The TREND IN ENGINEERING

at the University of Washington

Special issue

Graduate Program and Research Review

ATOMIC POWER: 1945-1955-1965?

RESEARCH IN THE COLLEGE OF ENGINEERING 1940-1955

AERONAUTICAL ENGINEERING

CHEMICAL ENGINEERING

CIVIL ENGINEERING

ELECTRICAL ENGINEERING

MECHANICAL ENGINEERING

SCHOOL OF MINERAL ENGINEERING

October, 1955

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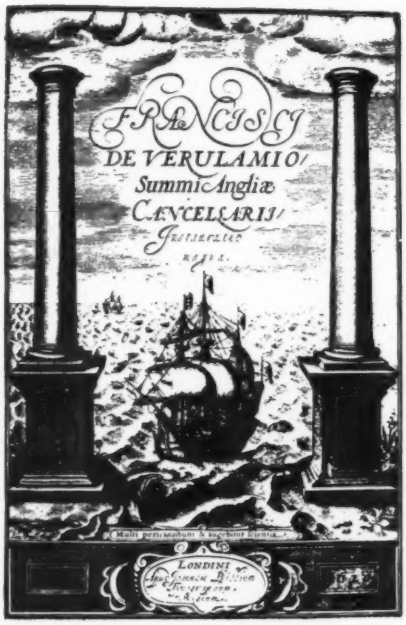
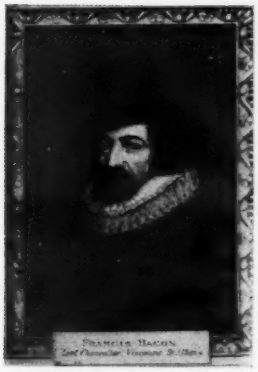


FRANCIS BACON (1561-1626) is one of the most controversial figures in English history. He wrote essays extolling the loftiest moral virtues yet, as Lord High Chancellor of England, confessed to accepting bribes which, however, he insisted did not influence his decisions! Two centuries after his death, he became the center of a cult which attributed to him the authorship of Shakespeare's poems and plays, as well as other contemporary classics. Hailed as the "father of modern science," he was apparently almost totally unacquainted with the work of the great scientists of his own time: Galileo, Gilbert, Harvey, Kepler, Vesalius.

What he did possess was the ability to set forth simply and clearly "the widening intellectual breach which separated the men of his day from the middle ages," so that Robert Boyle, a generation later, attributed the founding of the Royal Society to the influence of Bacon's writings. His *Novum Organum (A New Method)* sets forth his discovery of a "new" inductive logic based on *observation* and *experiment*, by which he believed future progress was to be made. The title indicates a departure from Aristotle's original *Organon*, but by the time science in the 19th century had succeeded in divesting Aristotle of the theological cerements in which scholasticism had embalmed him, the ideas of the two men appeared not so diverse.

The reproduction above shows the famous title page of the 1620 edition of the *Instauratio Magna (The Great Restoration)*, of which the *Novum Organum* is a part. It depicts, literally, the "Pillars of Hercules" which were believed by the ancients to mark the boundary of the known world. A ship under full sail is about to venture boldly beyond them into the uncharted seas of "the new science." Below the landscape, in Latin, is the prophecy: "Many will pass beyond and knowledge will be increased." (The so-called "Pillars of Hercules" of the ancient world were actually, of course, the two promontories at the eastern end of the Strait of Gibralter.) Bacon, himself, in deploring the inability of men to realize fully their reasoning powers, wrote: "And hence the sciences seem to have their Hercules' Pillars, which bound the desires and hopes of mankind."



SOME HIGHLIGHTS *on* GRADUATE STUDY *in* ENGINEERING *

"The Purpose, to Search Out, Guide and Form a mind nimble and versatile enough to catch the resemblance of things and at the same time steady enough to fix and distinguish their subtler differences; as being gifted by nature with desire to seek, patience to doubt, fondness to meditate, slowness to assert, readiness to consider, carefulness to dispose and set in order . . . that neither affects what is new nor admits what is old, and hates every kind of imposture . . . a kind of familiarity and relation with Truth. . . .

"Read not to contradict and confute, nor to believe and take for granted, nor to talk and discourse, but to weigh and consider. Some books are to be tasted, others to be swallowed, and some few to be chewed and digested. Reading maketh a full man, conference a ready man, and writing an exact man . . ."

FRANCIS BACON

Philosophy and Objectives

Graduate study in engineering is a part of the general process of education. We are trying to prepare a whole man to live a full life in a whole world. This statement is too general to be very useful in formulating curricula or setting standards for degrees, but it is important not to forget such ideals. There are important differences between undergraduate and graduate students, but the difference is more one of developing personal responsibility and of the implied need for scrutinizing evidence than one of overall objectives. At times study of a subject on the graduate level should proceed much less rapidly than on the undergraduate level because we must take time to examine assumptions critically; at other times it should proceed much more rapidly because the undergraduate studies have removed some . . . obstacles. . . .

Graduate work should be highly individualized and the student should be put more and more on his own responsibility until finally he has a more profound idea of what is meant by accuracy of statement and learns to judge with humility. Too much emphasis on discussion instead of analysis produces a man who can argue all sides of questions but is so trained that he cannot settle anything; yet too great elaboration upon the analytical method may produce a pedant. We must and can reconcile these extremes but there is, in this regard, much room for improvement in graduate teaching. . . .

The Superior Undergraduate Student

There is a minority of undergraduate engineering students who can benefit from a departure from the conventional program. . . . Such students may be identified by unusual ability and an enthusiasm and interest in topics beyond the curriculum. These students can benefit from a greater amount of basic theoretical work substituted for some of the work in practical engineering which in view of the rapidly advancing technology of our day inescapably is subject to rapid obsolescence. They can also benefit by being allowed greater freedom in selecting courses, thus moving in the direction of an individual study program. For selected students, there should be available . . . some courses from a first-year graduate study program including contact with those engaged in research. Language work which will be needed as part of a program of advanced study should be initiated.

General Education for the Graduate Student

A recognized objective which is being implemented at a few institutions is that of continuance of general education outside the fields of engineering and science at a serious and mature level. This is particularly important for those who expect to become engineering teachers. The growing broad responsibilities of all engineers further justify increasing attention to this objective. Culture can, of course, be acquired by penetrating self-study in a variety of fields or assimilated by close association with scholars. Its acquisition is seldom neglected by those who are

(Continued on page 36)

*These paragraphs, including the quotations from Bacon, have been arranged from the *Manual of Graduate Study in Engineering* by the Graduate Committee of the ASEE, 1952. *Ed.*

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgical, Ceramic Engineering
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. Results of major investigations are published in the form of bulletins and reports. Current research findings from the Station's fellowship projects, as well as accounts of its activities, appear in the quarterly journal, *The Trend in Engineering at the University of Washington*. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

October, 1955

The TREND

IN ENGINEERING

at the University of Washington

Vol. 7 No. 4

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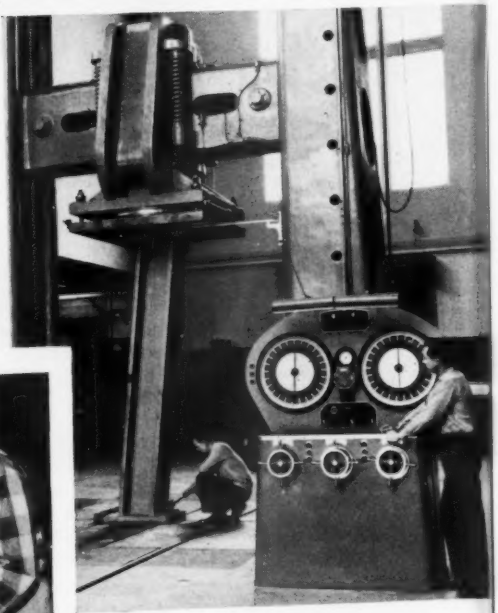
FRONTISPIECE

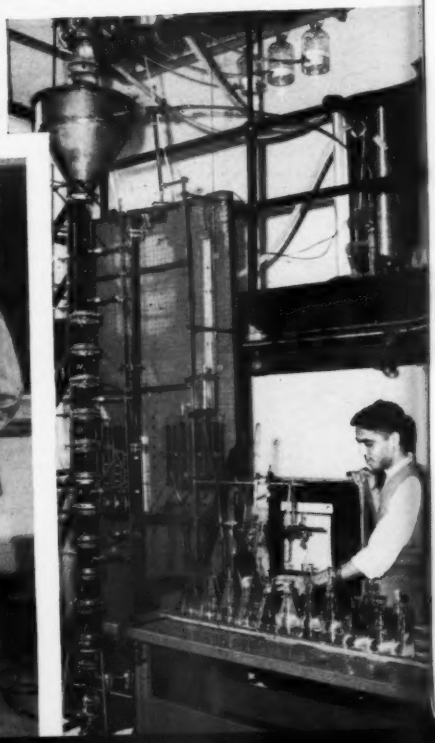
Shown clockwise from upper left are (1) a corner of the E.E. Communications Laboratory; (2) students measuring strain and deflection of a beam in the M.E. Laboratory; (3) large testing machine in the C.E. Structural Research Laboratory undergoing calibration of lateral stiffness; (4) Moti Shakani, Ch.E. graduate student, with continuous countercurrent apparatus for ion exchange resin separation; (5) Prof. F. D. Robbins *(right)* and student, with large oscilloscope designed for E.E. classroom demonstration; (6) Cer. E. student withdrawing test specimens from high-temperature kiln; (7) students in the Physical Metallurgy Laboratory; (8) M.E. students testing a wood beam. *Center: (above)* brittle failure in large tensile specimen with reinforced cutout; *(below)* Dr. R. E. Street *(left)* and graduate student Jerry Upton, with test section of the A.E. intermittent 3″ x3″ supersonic wind tunnel ($M = 5$).

Note: All photographs in this issue, with the exception of those of Professors Farquharson and Ganzer, are the work of the University of Washington Still Photography Production Unit.

UNIVERSAL HYDRAULIC
TESTING MACHINE
60,000 POUNDS CAPACITY
TENSION OR COMPRESSION



ATMOSPHERE
FURNACE
TEMPERING
FURNACE



Atomic Power: 1945-1955-1965?

HAROLD E. WESSMAN

Dean of the College of Engineering and member, since 1950, of the ASEE Committee on Nuclear Engineering Education

1945: The news of the blast that destroyed Hiroshima had been flashed around the world. The tremendous, awesome energy released by the splitting of the atom was manifest to everyone. But how could this uncontrolled chain reaction which had destroyed a city be curbed, and the energy of nuclear fission be converted into useful, economical power for peacetime purposes? That was the question presented to engineers and scientists by the nation's leaders.

As the story of the development of the atomic bomb slowly unfolded, we learned that in a 5-year period, from 1940 to 1945, hundreds of scientists and engineers and thousands of skilled workers had wrought a miracle in an unbelievably short time. This they had done because modern warfare had demanded it. Although no one man can receive the credit for the successful operations at Hanford and Oak Ridge and Los Alamos, which culminated in the atomic bomb, we must never forget the small group of scientists who initially pointed the way toward the goal.

The world-famous Einstein equation showing the energy inherent in the atom had presented a challenge since 1905 to scientists everywhere, but no one individual had the combined mental and physical resources to produce a practical demonstration that

$$E = MC^2.$$

The implications of this equation are startling. The energy, E, resulting from the complete conversion of a one-kilogram mass, M, equals 25 billion kilowatt-hours. In the above equation, C is the speed of light, and when this value is squared, the resulting factor is obviously very large. The magnitude of the challenge becomes evident when we recall that the heat energy given off by the burning of 1 kilogram (2.2 pounds) of coal is only 8½ kilowatt-hours.

Just prior to 1940, small-scale laboratory experiments had demonstrated that a radioactive isotope of uranium, U-235, could be split by neutron bombardment. Enough knowledge had been accumulated to indicate that both controlled and uncontrolled chain reactions were possible, that sustained fission would produce enormous amounts of energy. A few physicists knew that highly fissionable plutonium could be produced from natural uranium, which contains over 99 per cent of U-238 and less than 1 per cent of the isotope U-235.

The terrifying possibilities of an atom bomb became evident to the top leaders of our nation at the

outbreak of World War II. Unlimited funds and resources were immediately made available to achieve this one goal — the *atom bomb.*

The first successful chain reaction, a controlled reaction, was achieved by Enrico Fermi on December 2, 1942, in his small reactor or pile beneath the concrete stadium at the University of Chicago. This great physicist had not only developed the theory of the chain reaction — he had now proved it with his lattice-work cube of uranium and graphite.

The history of the next three years cannot be related here. We know that the huge piles or reactors at Hanford were successful in taking neutral uranium slugs, and by controlled fission, converting them to plutonium-loaded slugs. We know that complex chemical processing succeeded in extracting the plutonium from these slugs and in shaping this element into usable form. The bomb over Hiroshima (and the previous test bomb at Alamagordo) demonstrated that when two slugs of plutonium with combined mass greater than a certain critical value were brought together instantly in a single bomb, the result was an uncontrolled reaction, a terrific blast which could destroy a city and kill thousands of people. We had also learned that another type of process, the gaseous diffusion process for separating fissionable uranium, U-235, from U-238, had proved unbelievably successful in the huge plant at Oak Ridge. The military goal had been achieved. The cost? Over 3 billion dollars. Was it worth it? Unquestionably! Without this weapon, we and the other free nations might even now have lost our freedom, our lives, and untold billions of dollars to some other nation with skilled scientists and engineers.

1955: What has happened in the ten years since 1945? Are we closer to the goal of usable economical nuclear power for peacetime purposes? The answer is: Yes — very much closer. But there is still work to be done in research and development before any sizeable amount of power will be generated from nuclear fission.

Let us trace briefly the history of the past decade. The big reactors at Hanford were producing tremendous amounts of heat which was dissipated by cooling water from the Columbia River. The possibilities of producing power from this heat energy could not be overlooked. But the Hanford piles were too costly for peacetime competition in the field of power generation.

For several years after the close of World War II, further development proceeded slowly while Congress perfected legislation creating the Atomic Energy Commission. Then, in 1947, expansion of the Hanford plutonium plant began. The Argonne Laboratory near Chicago and the Los Alamos center were revitalized. In 1948, the expansion of the Oak Ridge plant to produce more U-235 was initiated. In 1949 the Russians exploded an atom bomb and the Hanford and Oak Ridge programs were accelerated. Early in 1950, the President ordered the beginning of work on the hydrogen bomb. Then the war in Korea began. The result was more expansion, but the major emphasis was on weapons development. Another plutonium plant was started at Savannah, a plant also capable of producting tritium. Another gaseous diffusion plant was started at Paducah.

It is no secret now that the work on the hydrogen bomb, a far deadlier weapon than the atomic bomb, has been highly successful. A citation in July, 1954, from President Eisenhower to the Los Alamos Scientific Laboratory testifies to the remarkable accomplishments in fusion, or thermonuclear, weapons.

Now it would seem from this recital that all of the emphasis of the Atomic Energy Commission has been directed towards military weapons. That is not so. The Commission has never lost sight of the possibilities of atomic power, both for special military purposes and for peacetime uses. Initial efforts along these lines were concentrated in three sectors at the National Reactor Testing Station in Idaho based on design and development studies made chiefly at the Argonne Laboratory. The first was a materials-testing reactor which has provided much valuable information on the effects of radiation on uranium fuel elements and their containers, and also on materials that might be used as cooling water tubes or as coolants. The second reactor was the remarkable breeder reactor which has demonstrated that more fuel can be produced than is consumed in the same reactor. In other words, this reactor proved that one unit can produce heat energy from the fission of uranium 235 in natural uranium and at the same time convert the remaining uranium 238 in the natural uranium into fissionable plutonium which can also be used as fuel to produce energy. The significance of this becomes manifest when we recall that the readily fissionable uranium 235 is not plentiful. It occurs in natural uranium only as one part in 140. The remainder is U-238.

The third reactor at the Idaho test site was the Submarine Thermal Reactor with a cooling system of pressurized water. This unit served as the experimental prototype for the reactor subsequently installed in the submarine, *Nautilus.* Another major experiment was the homogeneous reactor at Oak Ridge in which the uranium fuel elements are actually in solution in ordinary water. The water serves both as moderator and coolant. Much valuable information has been obtained from every one of these reactor experiments.

On August 30, 1954, the President signed the Cole-Hickenlooper Bill, known as the Atomic Energy

Act of 1954. This significant law places a new emphasis on the peacetime uses of atomic energy. It specifically directs the Atomic Energy Commission to expand its research activities in the generation of usable nuclear power. The Commission immediately proceeded with plans for a Five-Year Power Reactor Development Program, a program aimed to achieve an economical solution of the problem of nuclear power. Five different types of power plants have been designed, and construction has already been initiated. A 60,000-kw plant with a *pressurized ordinary-water reactor* is under construction near Pittsburgh, Pa., in cooperation with the Duquesne Light Company. This plant will also produce a heat output of 264,000 kilowatts. A *boiling-water reactor* using ordinary water will be erected at the Argonne National Laboratory with an electrical output of 5,000 kilowatts and a heat output of 20,000 kilowatts. A *sodium-graphite reactor* has already been initiated at Santa Susana, California, in co-operation with North American Aviation. This will generate 20,000 kilowatts of heat energy. An experimental *fast breeder reactor* using sodium as a coolant is to be constructed at the National Reactor Testing Station in Idaho. This plant will generate 15,000 kilowatts of electrical energy and 62,500 kilowatts of heat energy. The fifth major reactor experiment will be a *homogeneous reactor* at Oak Ridge in which the uranium fuel is actually a liquid in solution in heavy water which serves both as a moderator and as a coolant. The electrical output will be 300 kilowatts and the heat output, 5,000 kilowatts.

Plans have also been made to surround the chain-reacting core in another homogeneous reactor experiment with a blanket of thorium which will breed U-233. This reactor will generate 16,000 kilowatts of electrical energy and 65,000 kilowatts of heat energy. The recent Geneva Conference brought out considerable agreement among British, Dutch and American scientists as to the advantages of a liquid reactor with a solution of fissionable uranium surrounded by a blanket of thorium-bismuth which breeds U-233, another fissionable isotope, which can then be recycled as fuel. Chemical processing of the spent fuel is also simplified in the liquid reactor.

Public announcement of this Power Reactor Program, together with the news early in 1955 of the successful sea trials of the nuclear-powered submarine, the U.S.S. *Nautilus,* virtually started a chain reaction of interest in atomic power throughout the world. The International Conference on Peaceful Uses of Atomic Energy at Geneva last summer heightened that interest. Much valuable information was exchanged there by scientists and engineers. But the event which "stole the show" was the announcement by the Westinghouse Company that they had a new product for sale, a 10,000-kw package power plant with a pressurized water reactor as the prime source of energy. The price? $4,000,000—in other words, $400 per kilowatt of capacity. That is still too costly!

1965: Where will we be ten years hence? Will we have 10,000,000 kilowatts of installed nuclear power by 1965? Great Britain has just announced plans to build 16 atomic power stations to supply the nation's electricity. The first of these, Calderhall, is now under construction and is scheduled to go into operation next year. Recently, Mr. F. K. McCune, Vice-President, General Electric Company, predicted that in 25 years we would see over 100,000,000 kilowatts being generated by nuclear power.

A second submarine, the *Sea Wolf,* with a liquid metal reactor, differing considerably from that in the *Nautilus,* will begin its sea trials shortly. Design studies for a nuclear-powered aircraft carrier and other large ships are under way. Are oil-fired naval ships on their way out? Many think so. No navy captain enjoys the repeated refueling at sea which is now necessary. How about commercial liners and freighters? Will they be nuclear-propelled in the future?

An aircraft nuclear-engine program is already under way. Will we see large planes with reactor engines circumnavigating the globe in 1965 with no stops for refueling?

These are fascinating questions. But the one which interests most engineers and industrialists is, "Can we achieve economical, competitive, nuclear power generation on a large scale?" I believe the answer is: Yes! $400 per kilowatt now is too much. But science and engineering, coupled with the competition of free enterprise, are bound to reduce costs. Tremendous advances in nuclear technology are inevitable. The reactor experiments noted previously, plus additional pilot plants, will add much to our knowledge. The result will be millions of kilowatts of atomic power.

The engineering schools of this country obviously are faced with a new responsibility, the education of the young nuclear engineers and the technicians who will be needed in ever-increasing numbers, and the re-education of many engineers now in practice. The Atomic Energy Commission, through its fine training programs at Oak Ridge and Argonne, and the big AEC contractors, such as the General Electric Company with its in-service training program at Hanford, have provided an excellent nucleus of engineers with a background in nuclear technology. But the primary responsibility for such education in the future must be carried by our engineering schools. The American Society for Engineering Education has a Committee on Atomic Engineering Education which has worked

(Continued on page 34)

Research in the College of Engineering

1940-1955

F. BURT FARQUHARSON

Director, Engineering Experiment Station

F. Burt Farquharson

The War Years

Prior to 1940, research at the graduate level hardly existed in the University of Washington College of Engineering. However, during the war years three significant projects were initiated which assumed very respectable proportions and eventually expended a total of approximately $960,000.

In the Civil Engineering Department, research on the Tacoma Narrows Bridge started in 1939 and continued until the new bridge was completed in 1950. Investigation of the cause of failure of the original bridge continued during the war and finally resulted in the development of a new and stable design for the new bridge. Following the war, research continued on the new structure and involved a number of phases in addition to the aerodynamic stability of the structure. During this period three members of the faculty and 12 graduate students were employed in the Structural Research Laboratory. Among the problems involved were the construction of a static model for guidance in the erection of the new bridge and a full-scale test on the light-weight concrete deck, investigating the integration of the open gratings with the concrete structure. The total expenditure on the Tacoma Narrows project exceeded $460,000. A total of 28 reports were submitted to the Advisory Board on the Investigation of Suspension Bridges and five separate parts of Experiment Station Bulletin No. 116 have been published. Up to the present time, over 17,000 copies of the parts of this bulletin have been distributed.

In 1941 the International Salmon Fisheries Commission received an appropriation of $2,000,000 for the design and construction of a series of fishways in the Hell's Gate Canyon of the Fraser River in British Columbia. The experimental and design work on this project during 1941-43 was directed by Professor C. W. Harris, of the Department of Civil Engineering, assisted at various times by four members of the faculty. The total expenditure for these studies was approximately $50,000.

In 1944 the pulp and paper mills of the State of Washington banded together to sponsor an intensive investigation of the pulp and paper problems of the region. Work has been conducted in three fields:

1) Basic research in wood chemistry and lignin
2) Utilization of pulp and paper mill wastes
3) Disposal of pulp and paper mill wastes

During the eleven years over which this investigation has extended, a total appropriation of $450,000 has been made. A total of more than 50 technical papers have been published and approximately 150 preliminary reports have been made to the sponsors. Twenty-five graduate students have assisted in this program and a number of master and doctoral theses have developed from these efforts.

The major portion of the work has been in the Department of Chemical Engineering, under the direction of Dr. J. L. McCarthy. A significant part of the task has fallen to the responsibility of the Department of Chemistry where Dr. D. L. Ritter has been in charge.

Post-War: Ten Years of Expanded Graduate Effort

A modest grant from the 1945 legislature (in the form of a special bill) provided the base for an expansion at that time in the field of graduate studies. Funds were made available for subsidizing 10 graduate students per year, for a two-year period, with a small additional sum for laboratory expenses. These funds became available just as the post-war influx of students began to take shape, and encouraged the extension of graduate work to all departments of engineering. Prior to this time the only serious graduate effort had been confined to the Department of Chemical Engineering.

The Engineering Experiment Station, which had been inactive during the war years, was reorganized with the development of a full graduate program as its chief function.

The 1947-49 Legislature provided funds through the regular University budget for a considerably expanded program dedicated to graduate instruction

and research, and included a generous allowance for research equipment in the various departments as well as a provision for the publication of bulletins and reports. In 1948 a quarterly publication, *The Trend in Engineering at the University of Washington,* was launched under the direction of a full-time editor who has also edited all other publications of the Engineering Experiment Station. The mailing list for *The Trend* now includes nearly 2,500 engineers in the state, 154 state industries, 263 deans and 496 department heads of engineering colleges in the country, 263 U. S. and 190 foreign libraries, as well as a considerable number of state and federal agencies. For the October, 1955, issue of the quarterly, 5,500 copies were printed.

The expanded graduate program also offered suitable grounds on which to approach the Walker-Ames Committee* with the request for a special lecturer, the first to be appointed in an engineering field. In the fall of 1947, Dr. Cornelius Lanczos, at that time with the Boeing Airplane Company, gave ten lectures on "The Fourier Series and Its Application." The 350 copies of his notes were soon exhausted, and occasional requests for them are still being received. In the spring of 1950, Dr. W. Prager of Brown University lectured on "The Extremum Principles of the Mathematical Theory of Elasticity and Their Use in Stress Analysis." These lectures were later issued as Bulletin No. 119.

Spring of 1954 saw two more Walker-Ames engineering appointees on the campus. Dr. H. W. Liepmann of the California Institute of Technology discussed "Modern Problems of Fluid Mechanics," at the request of the Department of Aeronautical Engineering, and Dr. N. W. McLachlan, visiting professor at the University of Illinois, was appointed Walker-Ames professor in Electrical Engineering, his subject being "The Complex Variable Theory and Transform Calculus."

During the ten years following the war the total number of graduate students enrolled in the College of Engineering rose to 231 in 1955. During this period the average number of graduate student subsidies has been approximately 40 per year from all sources including government and industry, and the stipend has been increased to $150 per month as of October 1, 1955. The subsidized student is required to devote one-half of his time to an assigned research problem, from which his thesis is derived, with the balance of the time devoted to formal graduate course work. Many of the projects initiated by the Engineering Experiment Station have resulted in continued and enlarged projects under government or industry sponsorship.

The past ten years have involved an expenditure of $1,168,239 of University funds and approximately an equal sum from Government and industry, with 495 individual graduate students providing the technical assistance under the subsidy program.

These efforts have resulted in many reports to sponsoring agencies and numerous articles in the technical press. A total of 97 reprints and 41 publications, including 27 issues of *The Trend* have been issued by the Experiment Station. A total of 179,405 pieces of literature have been distributed during the last ten years.

During this period, a number of projects, which not only have been of outstanding interest, but also directly concern the resources of the state and the well-being of its people, may be recalled at this time.

Highway Research. One of the most important research projects in the Engineering College has been conducted under the sponsorship of the Washington State Council for Highway Research, of which Professor R. G. Hennes of the Civil Engineering Department has been chairman since the establishment of the Council in 1951. Six separate projects have been authorized to date, of which four have been completed. The total appropriation for these six projects to date has been $229,767 and eight reports have been made to the Council. Washington State College has co-operated in several phases of this investigation. This total effort represents the first major attempt in this State to view the highway problem as a whole, and promises to be of inestimable value in the further development of the highway system. These projects are under the general supervision of Professor Hennes, with Willa Mylroie, research assistant professor, in direct charge of the large staff. During the last year a total of 38 persons were employed, including seven part-time faculty members, three full-time research workers, a statistician, 22 graduate students, and five undergraduates.

Power-Programming Studies. A most interesting problem, recently initiated through the co-operation of Seattle City Light, involves the application of digital computers to power-system problems. It is anticipated that the new program will supplement, and perhaps extend, the analytical procedures at present handled on power-system network analyzers. Dr. Laurel J. Lewis, of the Electrical Engineering Department, is in charge of this program and will be assisted this year by another member of the Electrical Engineering staff and a half-time graduate research

* The Walker-Ames Fund of $450,000 was set up in 1936 as provided by the will of Maude Walker Ames, who died in 1931, that, on the death of her husband, Edwin Gardner Ames, this bequest should be made, "that the University of Washington might, in financial competition with other important universities of the world, be able to guarantee the State of Washington the scholarly and educational services of the most distinguished minds available in this and other countries." The Walker-Ames Committee makes selections from among the scholars proposed each year by the various divisions of the University.

assistant. This investigation has been made possible by the recent acquisition, by the University, of an IBM electronic digital computer, Type 604.

Stream-Flow Predictions. In June, 1952, the Bonneville Power Administration entered into an agreement with the Civil Engineering Department and the Department of Meteorology and Climatology for a stream-flow research program. With additional storage reservoirs and power generation continually being developed on the Columbia River and its major tributaries, the problem of accurate and continuous evaluation of the power potential of the river has assumed increased importance. Advance warning of the magnitude and timing of changes in flow is necessary for the efficient operation of the BPA and its interconnected systems. The research program was therefore set up to develop procedures whereby increased flow from snowmelt or precipitation could be forecast for short periods from weather records or from forecasts of weather on many of the major tributaries of the river.

The University was represented in this work by Dr. Phil E. Church, head of the Department of Meteorology, and Professor Thomas H. Campbell, of the Department of Civil Engineering. Two graduate students worked on the project.

A total of six reports presenting forecasting procedures on several tributaries were presented before budget reductions in the BPA forced the abandonment of this project.

The Heat Pump as a Source of Residential Heating. In 1946 a growing public interest in the heat pump as a source of residential heating inspired a research project in this field. Professor G. S. Smith of the Electrical Engineering Department has been in charge of this project which was initiated through the Engineering Experiment Station. Eventually the Bonneville Power Administration entered into a cooperative agreement with the University for a more extended study. Seven graduate students have used this project as a source of thesis material for Master's degrees, and ten publications have resulted from the studies. This project has received a great deal of attention throughout the State as represented by heavy correspondence and requests for copies of Technical Note No. 6, "The Heat Pump for Residential Heating," and reprints of three articles.

Olivine in the State of Washington. The two largest deposits of olivine in Washington are found in the Twin Sisters Mountain region, about 10 miles southwest of Mount Baker and approximately 80 miles north of Seattle, and on the southeast corner of Cypress Island about 80 miles northwest of Seattle. The deposit at Twin Sisters Mountain is the largest known single deposit in the United States, covering 25,600 acres, with an estimated potential yield of 450 million pounds of the mineral annually over the next 500 years.

At the University of Washington, interest in the possible uses of these huge olivine deposits originated as early as 1934, with Professor Hewitt Wilson, of the College of Mines, in co-operation with the Northwest Experiment Station of the U. S. Bureau of Mines under its director, Dr. H. F. Yancey. Investigations chiefly concerned the refractory properties of olivine, but some work was done on its use as a foundry sand, and several other directions of future study were pointed out. Eight M. S. theses were produced as a result of this study, 1934-42.

Later research in the Division of Ceramic Engineering, under the direction of Dr. J. I. Mueller, investigated olivine as a constituent in dinnerware and wall-tile bodies, making use of its ability to lower the melting point of other materials present, thus forming a dense wear-resistant mass at a relatively low temperature.

In 1946-47 the availability of phosphate rock, olivine, and low cost electrical power in the Pacific Northwest prompted research by the Department of Chemical Engineering in co-operation with the Bonneville Power Administration toward producing a phosphatic fertilizer by the fusion of phosphate rock with olivine. A process, developed under the supervision of Dr. R. W. Moulton, was put into commercial practice on a small scale. Dr. Moulton also investigated the production of magnesium from olivine ore by several methods. Several M.S. theses were written by graduate students assigned to these projects.

In the fall of 1950 the Shops Division of the Mechanical Engineering Department started an extensive investigation into the use of olivine sand as a refractory aggregate for foundry use. This study, under the guidance of Professor Gilbert Schaller, has been carried on by Professor William A. Snyder and a graduate student. The mineral not only has proved to be an excellent foundry material, superior technically to silica, but the non-toxicity of olivine dust is considered to be a point of great social significance. Five articles and a Master's thesis have reported the results of this investigation.

Engineering Geology. An important study involving the geological formation of the Seattle area has been carried on under the direction of Dr. J. Hoover Mackin of the Department of Geology. The glacial map of Seattle is the result of painstaking detailed mapping of outcrops in the metropolitan area. With the great amount of construction of new highways, tunnels, buildings, etc., in Seattle, the map has been a great help to engineers and contractors. Twenty-five reproductions of the complete report on the glacial geology of Seattle as embodied in the M.S.

thesis by W. R. Stark and D. R. Mullineaux, Engineering Experiment Station fellows, have been distributed. It is hoped that a more extended co-operative investigation may be undertaken in the near future.

Washington Coal. The only large coal field on the Pacific Coast is in Washington, and the largest area of coal-bearing rocks lies south of Seattle extending through King, Pierce, Thurston, Lewis, and Cowlitz counties. The major reserves in this area are subbituminous in rank. Smaller reserves, principally of bituminous and higher rank, totaling some 12 billion tons, occur in Whatcom, Skagit, King, Snohomish, Pierce, and Kittitas counties. An estimate of subbituminous coal reserves in Washington is approximately 52 billion net tons. The high production costs and increased use of oil and coal of higher rank caused a decrease of over 50 per cent in the production of Washington subbituminous coal from 1937 to 1948.

One potential outlet for this low-rank coal has been suggested by Professor F. D. Robbins of the Electrical Engineering Department, in his study of steam plants for power production to meet the urgent need for increased power in the Northwest. Professor Robbins has pointed out that steam plants, especially if equipped with late-model cyclone furnaces, could meet this need with the advantages of speedier construction and more economical operation than additional hydroelectric plants. Three articles in *The Trend* have reported his investigations.

In 1950, Dr. Lorenz A. Conradi of Norway, during his research assistantship in the Engineering Experiment Station, produced EES Report No. 6, "The Chemical Utilization of the Subbituminous Coals of Washington," which brought together available data on this potential state resource and discussed all the important processes used in the United States and abroad for chemical utilization of low-rank coals.

In the Department of Chemical Engineering a succession of graduate students under the direction of Dr. Moulton have investigated the gasification of Washington coal by the use of oxygen and steam, and have designed and carried out tests on a gasification pilot plant. A doctoral dissertation, five M.S. theses, and several articles in *The Trend* reported the results of this work.

The Environmental Research Laboratory. In March, 1951, the Environmental Research Laboratory was established under the sponsorship of the Engineering Experiment Station with the following divisions of the University co-operating: Department of Public Health and Preventive Medicine, Department of Chemistry and Chemical Engineering, Department of Meteorology and Climatology, and the Sanitary Engineering Division of the Department of Civil Engineering. The Laboratory, launched with the assumption that it could be made self-supporting through service to industry and local divisions of government, operated on this basis for three years. In July, 1954, it was brought directly under the wing of the Medical School and is now functioning as a division of the Department of Public Health and Preventive Medicine.

Ross H. Kusian, a mechanical engineer, was brought in to direct the project shortly after its inception and has been responsible for its outstanding success.

Projects in air pollution have ranged from spot cases, such as investigation of sulfur dioxide poisoning in a community, to an Air Force sponsored investigation of the effect of rocket exhaust on neighboring areas. In its industrial health activities the Laboratory has conducted studies of such problems as industrial phosphine cases to year-long studies of the effect of insecticides on orchard workers. Many of these industrial hygiene projects are sponsored by the Safety Division of the Washington State Department of Labor and Industries, which retains the Laboratory on an annual basis.

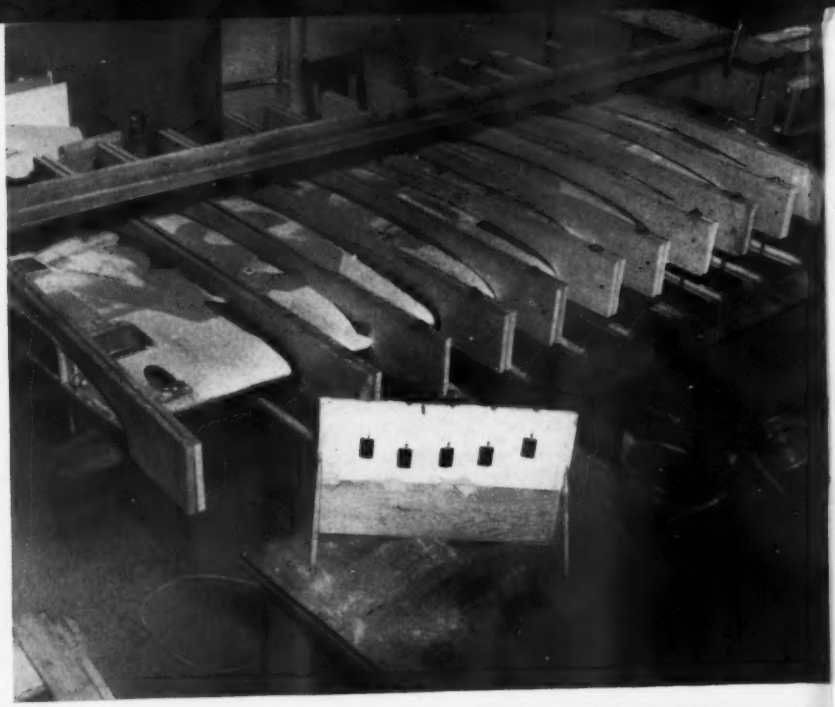
A major project of the Laboratory was the study of the Seattle air-pollution problem, sponsored by the City of Seattle, and carried on under the direction of Professor R. G. Tyler of the Sanitary Engineering Division of the Department of Civil Engineering. The detailed report, published in March, 1952, revealed the extent to which Seattle is involved in both local and regional air-pollution problems, and concluded with remedial recommendations.

High-Strength Steel Bolts vs. Rivets

A most important advance in structural practice during the post-war years has been the substitution of high-strength steel bolts for the conventional rivets in certain classifications of steel joints. The University of Washington entered this field of investigation in 1945 through a small grant from the State Toll Bridge Authority in connection with the rebuilding of the Tacoma Narrows Bridge. Several additional grants from the Research Council on Riveted and Bolted Structural Joints have supported this work continuously and the studies are still in progress. As a result of these investigations, and those in several other institutions, specifications for the new technique have been prepared and an ever-increasing use of this procedure is evident.

The Future

The past ten years of graduate activity have been very rewarding and have resulted in the growth of an engineering faculty increasingly conscious of the important relationship between good teaching and creative endeavor. The prospects for the next ten years are bright and should see the College of Engineering of the University of Washington assuming a major role in the development of the Northwest.



Aeronautical Engineering

V. M. GANZER
Executive Officer

V. M Ganzer

A survey of the research activity of the staff and students of the Department of Aeronautical Engineering for the period since 1953, when the last report was issued, shows that research has been carried on in several very important realms. Although the problems of flight in the high subsonic speed range, where modern transport airplanes will be flying in a few years, are not nearly completely solved, many of the more interesting and challenging problems are concerned with extremely high-speed flight, where high temperatures lead to what is now familiarly known as the "heat barrier," and with extremely low-speed flight, below the stalling speed of conventional aircraft.

As examples of the type of research being carried on in the first field, that of very high-speed flight, mention should be made of graduate work in the supersonic wind tunnels on the experimental approach to the transfer of heat to a surface, such as an airplane skin, from a supersonic stream of air. In the list of graduate theses will be found one by Don Graf, which is an example of the type of work being done on this subject.

On the more theoretical side of this problem is the work being done by Dr. R. E. Street on a project sponsored by the National Advisory Committee for Aeronautics. Dr. Street is making a critical study of the problem of slip flow in aerodynamics, especially with regard to the determination of the proper boundary conditions and the interrelationship between slip flow and viscous hypersonic flow. The ultimate aim of this work is a more precise determination of skin friction and heat transfer at supersonic speeds.

The low-speed flight regime is attracting more attention now than at any previous time. The definition of low-speed flight is relative, and may include flight at 100 miles per hour for a supersonic airplane, as well as at zero miles per hour for a hovering or vertical take-off machine. In general, low-speed flight may be attained through the use of flaps and boundary-layer control, by tilting the thrust axis to obtain a force to lift the airplane, or through the use of movable wing systems.

Research is being carried on in the field of moving wings in this department, and the wind tunnel has co-operated with companies approaching the problem from the standpoint of tilting thrust axes and flaps.

Professor F. S. Eastman is continuing his studies on a general approach to the problem of low-speed flight through the use of moving wings, and it appears that his work may lead to methods for selecting optimum configurations for particular purposes, and to new ways to improve low-speed flight for all types of airplanes.

Another project in the low-speed flight regime is one sponsored by the National Advisory Committee for Aeronautics on wind-tunnel wall interference on helicopter rotors. The object of this experimental study is to attempt to determine the factors which should be applied to force coefficients obtained from helicopter tests in a closed wind tunnel to make these coefficients equivalent to data obtained in free air, and to attempt to determine limiting operating conditions for rotors in a closed tunnel. The study is being supported by a grant of $28,820.00 and will be carried on by Mr. William Rae, Research Associate, under the direction of the writer.

The increase in airplane size and speed, the inclusion of sweepback in the wing and tail, and the trend toward unusual configurations, such as the delta wing, have increased the problems available to the structural researcher manyfold. Most of the work in this field has been done by Professors R. C.Weikel and H. C. Martin in consultation with the Boeing Airplane Company. Although much of this work is classified, several papers which resulted from this collaboration have been given at various meetings by Dr. Martin.

This report would not be complete without mention of the continuing role of the F. K. Kirsten 8′ x 12′ wind tunnel in the development of our airpower. Although, because of classification, most of the work done in this facility is not made public, the fact that the tunnel is occupied 60 to 80 per cent of the available time in each year by aircraft companies speaks for itself. For example, during the past year the Beech Aircraft Corporation of Wichita, Kansas, occupied the tunnel 26 per cent of the year, and Boeing used

OPPOSITE PAGE: *(Left)* **Professor R. C. WEIKEL, in the Aeronautical Structural Laboratory, using strain gages to measure deflection of a box beam under static loading;** *(right)* **measuring deflections of a wing with static loading;** *(below)* **Dr. R. E. STREET** *(right)* **and graduate student DON GRAF measuring heat transfer to heated plates in the 1″ x 2″ supersonic wind tunnel ($M = 2.6$).**

35 per cent of the available time, testing models of the B-47, B-52, Model 707 transport, and of airplanes which have not been made public as yet.

During the past ten years, the wind tunnel has taken in almost a half million dollars for services rendered. Although some of this goes for supervision, overhead, and equipment, much of it is used in the employment of approximately 20 undergraduate and graduate students, who work part time during the school year, and who are exposed to the research and development being carried on by the aircraft industry and under sponsored contracts. Furthermore, some of the wind-tunnel proceeds have been used directly for departmental research and research equipment. Examples of this are the work of Professor Eastman and the supersonic wind tunnels.

This report might close with mention of the contributions of the staff members by virtue of outside contacts. As mentioned previously, Professors Weikel and Martin have spent one day a week, as well as the summer months, working with Boeing on structural problems. Professor R. G. Joppa spent the summer of 1955 in the flight test department as a participant in the Boeing summer faculty program.

Publications: 1954-1955

Technical Articles

GANZER, V. M., "A Low-Lag Altimeter" **(with P. C. Wingrove),** *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

LIN, T. C., "Effect of Variable Viscosity and Thermal Conductivity on the High-Speed Slip Flow Between Concentric Cylinders" **(with R. E. Street),** NACA Tech. Report 1175, 1954.

STREET, R. E., "The Intermittent Supersonic Wind Tunnel," *The Trend in Engineering,* Vol. 7, No. 3 (July, 1955).

———, "Effect of Variable Viscosity and Thermal Conductivity on the High-Speed Slip Flow Between Concentric Cylinders" **(with T. C. Lin),** NACA Tech. Report 1175, 1954.

WINGROVE, P. C., "A Low-Lag Altimeter' **(with V. M. Ganzer),** *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

Graduate Theses: 1954-55

M.S. in Aeronautical Engineering

EES: Engineering Experiment Station Fellow

GILES, HARRY L.: Theoretical Ground Plane Effects on Span Loading for Wings Having No Sweep.

GRAF, DONALD A.: Experimental Investigation of Heat Transfer Coefficients on a Uniformly Heated Flat Plate with Zero Pressure Gradient and Laminar Boundary Layer at a Mach Number of 2.52. (EES)

NANEVICZ, STANLEY J.: An Investigation of the Statistical Methods of Generalized Harmonic Analysis and Their Applications to Problems in Airplane Dynamics.

RATTAUD, FRANCOISE: A Discussion of Airplane Flutter from an Elementary Point of View. (EES)

WINGROVE, PHILIP C.: A Low-Lag Altimeter. (EES)

WHAT HAPPENS TO AMERICAN EDUCATION WILL EVENTUALLY HAPPEN TO AMERICA

WHAT HAPPENS TO AMERICAN EDUCATION will eventually happen to America! That is the real meaning of the Council for Financial Aid to Education, which is an "invention" not of educators but of business men who have observed America's growing dependence on college-educated men and women and the increasing difficulties of financing its higher education. The Council was founded in 1952. Its public activities have been under way for over a year. They are being financed initially by four respected foundations: Carnegie, Ford, Rockefeller and Sloan.

Adolf A. Berle in a notable recent book, *The 20th Century Capitalist Revolution,* speaks of the significant increase, during the past few decades, in the "powers" of American corporations. In many areas of activity, he says they have been compelled to assume and to administer functions which formerly belonged exclusively to government . . . . "The really great corporation managements have reached a position for the first time in their history in which they . . . must consider the kind of community in which they have faith, and which they will serve, and which they intend to help to construct and maintain. In a word, they must consider at least in its more elementary phases the ancient problem of the 'good life.'"

The obvious great benefits to industry from our colleges and universities in trained personnel and in research is not the prime consideration in the Council's purpose to promote financial aid to higher education. Its directors regard American strength, security and prosperity in an uncertain world as dependent in no small measure upon the continuing ability of our colleges to produce educated talent. They are concerned, for example as are all citizens by reports, apparently authentic, that Russia is outpacing us in important fields of education; that last year, for instance, Russia graduated 40,000 trained engineers while our schools graduated fewer than 20,000.

But support of technical education as such is not our chief concern. The chairman of the board of General Motors Corporation, himself one of the Council's founders, has said of his own business: "Give us educated men. We can train them ourselves." Increasingly American business is interested in helping liberal education—liberal in the sense that it contributes to what the dictionary calls "independence of opinion, not servile, worthy of a free man." No business man needs to be told what "independence of opinion" has meant in the progress of American industry. Freedom may be dangerous. But it is the safest thing we have. This interest adds to the importance of preservation in vigor of our "dual system" of higher education financed and administered by the State and higher education financed and administered independent of the State.—Wilson Compton in *The Key Reporter,* Spring, 1955.

Chemical Engineering

R. W. MOULTON
Executive Officer

R. W. Moulton

The research program of the Department of Chemical Engineering has continued during the past two years at a high level of activity. The departmental staff consists of five permanent full-time faculty, two half-time instructors, and six teaching assistants. The graduate students number about 32, with approximately half being M.S. and half Ph.D. candidates.

Each member of the staff has been active in his own research field. The interests of the group do not overlap, so that, collectively, the department offers a well-rounded program. The various areas of research include important fields of fundamental research in chemical engineering and also deal with important natural products and industries of the state of Washington. The results of these investigations have been presented by various faculty members at national meetings and have also appeared in the leading chemical and chemical engineering journals.

Professor A. L. Babb has been interested in diffusional processes and in vapor-liquid equilibrium studies. He has also done considerable work in the field of electrochemistry and corrosion. He has been active in developing our process instrumentation laboratory and in the field of nuclear engineering education. As a result of his research and publications he obtained a grant from the Office of Ordnance Research for the support of his research program on Molecular Diffusion in Liquids. Dr. Babb has published several papers, has attended scientific meetings throughout the United States, and is making significant contributions in his field of research.

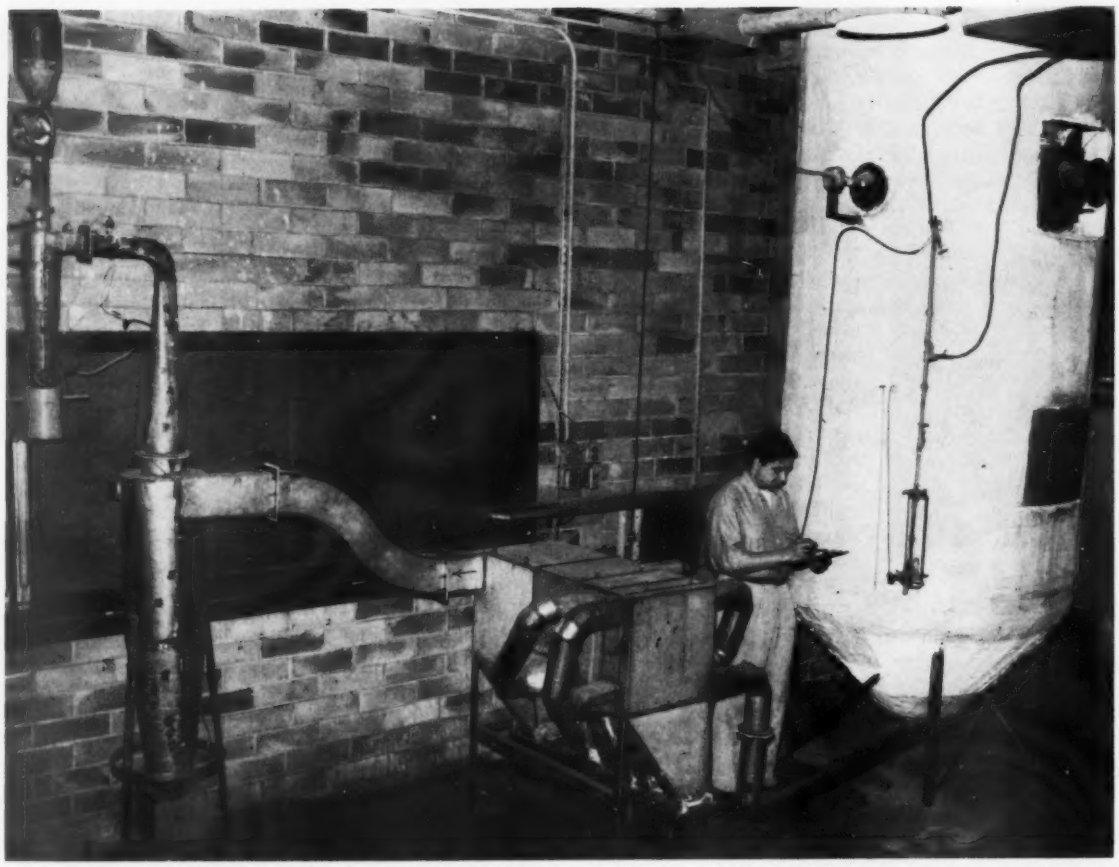
Professor M. M. David is now completing his second year in this department. He has initiated and has underway an active graduate research program. His research interests have been principally in the fields of heat transfer, unit operations, and ion exchange, particularly the mechanism of ion exchange, design and scaleup of exchange systems, and the cost estimation of ion exchange equipment. He has done work for various local industries and is employed for the summer of 1955 by the Boeing Aircraft Company.

Professor L. N. Johanson has been particularly interested in the fields of reaction kinetics, fluidized beds, and the cracking of petroleum. He has studied the mechanism of heat transfer in fluidized beds and is directing a research program which is being supported by the Texas Company and which deals with flow dynamics in fluidized beds. His students have studied the particle behavior and bubble behavior during fluidization, using motion-picture technique. He also has a grant from the Office of Ordnance Research for work in the field of catalytic reactions. This grant is for a two-year period, and supports work concerned principally with the role of adsorption upon the catalyst of reactants and products in heterogeneous catalyzed reactions.

Professor J. L. McCarthy has been active in the field of lignin and cellulose and other problems related to the pulp and paper industry. For the past 11 years the pulp mills of the state have jointly supported a research program at the University in the Departments of Chemistry and Chemical Engineering. The budget for the department of Chemical Engineering approximates $12,000 per year. Dr. McCarthy is a recognized authority in this field, and has made important contributions to the technical literature. He also receives financial support for his research program from the Technical Association of the Pulp and Paper Industry, the Hooker Electrochemical Company, and Rayonier, Inc.

The writer has directed his research activities principally along the lines of gasification of Washington coal, spray drying, and the electrolysis of fused salt mixtures. Work in these fields has resulted in several Ph.D. theses and publications in the technical journals. Support for this research program has been partially on a research grant from the Mathieson Corporation, a grant from the Procter and Gamble Company and also a grant from the Standard Oil Company of California. Work was initiated recently under a contract with the Department of the Interior on the topic of desalting salt water by freezing process. This is a joint project with the Mechanical Engineering Department.

All members of the staff have been active in other ways than in their research. Each one takes part in the work of the various professional societies. Many contributions of time and effort are made to city, county, state and federal agencies.



D. R. S. ARNI, EES research assistant in Chemical Engineering, with spray dryer which is being used for fundamental studies dealing with rates of drying.

*Publication: 1954-55**

Technical Articles

ANKER-RASCH, O., "Behavior of Celluloses in Sodium Hydroxide Solutions" **(with J. L. McCarthy),** *Norsk Industrie,* Oct., 1954. (Reprinted in *The Trend in Engineering,* Vol. 7, No. 3, July, 1955).

BABB, A. L., "Continuous Countercurrent Ion Exchange I: Resin Particle Settling Rates in Spinner Columns" **(with J. Olin, W. W. Koenig, and J. L. McCarthy),** *Chem. Eng. Prog.,* Symposium Series, **50,** 14, 103 (1954). EES Reprint No. 90.

———, *Ibid.* "II: Mass Transfer Rates in Spinner Columns **(with W. W. Koenig, J. Olin, and J. L. McCarthy),** *Chem. Eng. Prog.,* Symposium Series, **50,** 14, 111 (1954). EES Reprint No. 91.

———, "Scintillation Counting Applied to Vapor Phase Analysis" **(with K. L. Mai),** *Nucleonics,* 13, 2, 52 (1955). EES Reprint No. 94.

———, "Vapor-Liquid Equilibria of the System Carbon Dioxide-Hydrogen Sulfide-Sodium Carbonate-Sodium Bicarbonate-Sodium Sulfide-Water" **(with K. L. Mai),** *Ind. and Eng. Chem.,* Sept., 1955. EES Reprint No. 99.

BUCKHAM, J. A., "Factors Affecting Gas Recirculation and Particle Expansion in Spray Drying" **(with R. W. Moulton),** *Chem. Eng. Prog.,* **51,** 3 (Mar., 1955).

DAVID, M. M., "The Application of Ion Exchange to the Treatment of Dilute Brass Mill Wastes" **(with R. H. Bliss),** *Trans. Indian Inst. of Chem. Eng.,* V, 1 (1952-53).

———, "A Chemical Engineering Laboratory Course," *ibid.,* p. 35.

DAVIS, R. E., "Lignin IV. Electrophoresis Study of Alkaline Cleavage Products from Lignin Sulfonates **(with E. T. Reaville, Q. P. Peniston, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* **77,** 2405 (1955). EES Reprint No. 96.

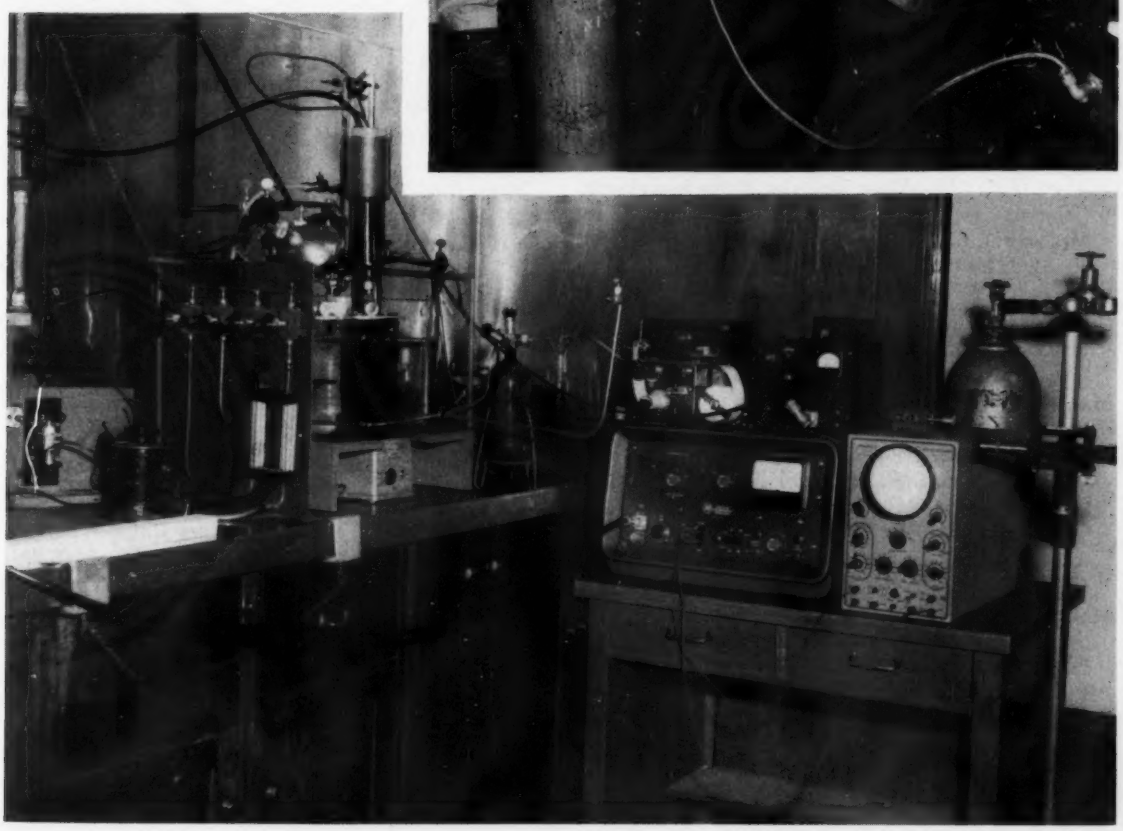
* Also publications 1953-54 not reported in *The Trend,* Oct., 1954.

RIGHT

GLENN OTTERBEIN, EES research assistant in Chemical Engineering, with apparatus for measurement of self-diffusion in alcohol-water systems, using radioactive tracers. He is inserting the combination diffusion cell-scintillation counter in the constant temperature bath.

BELOW

Apparatus used by K. L. MAI, graduate student, in the determination of vapor-equilibria of the system $CO_2 - H_2S - Na_2CO_3 - Na_2S - H_2O$. A continuous analysis of the liquid phase was obtained by pH and conductance measurements, and the composition of the vapor was determined continuously by a scintillation-counting technique employing sulfur–35 as the radioactive tracer. This system is of practical importance in the development of sulfur-recovery processes. Dr. Mai wrote his doctoral dissertation on this study.



Felicetta, V. F., "Equilibrium Distribution of Ammonium and Other Ions Between Cation Exchange Resins and Aqueous Solutions: Sulphite Spent Liquor V" **(with A. E. Markham, J. L. McCarthy),** *TAPPI,* Vol. 37, No. 10 (Oct., 1954). EES Reprint No. 88.

———, "Lignin VI. Molecular Weight of Lignin Sulfonates by Light Scattering" **(with J. Moacanin, W. Haller, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* 77, (1955). EES Reprint No. 98.

Franklin, F. C., "Flow of Granular Material Through a Circular Orifice" **(with L. N. Johanson),** *Chem. Eng. Sci.,* 1955.

Glennie, D., "Lignin V. Vanilloylformic Acid from Alkaline Cleavage of Lignin Sulfonates" **(with H. Techlenberg, E. T. Reaville, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* 77, 2409 (1955). EES Reprint No. 97.

Haller, W., "Lignin VI. Molecular Weight of Lignin Sulfonates by Light Scattering" **(with J. Moacanin, V. F. Felicetta, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* 77, (1955). EES Reprint No. 98.

Johanson, L. N., "Fluidized Bed Heat Transfer" **(with W. W. Wamsley),** *Chem. Eng. Prog.,* 50, 347 (1954).

———, "Flow of Granular Material Through a Circular Orifice" **(with F. C. Franklin),** *Chem. Eng. Sci.,* 1955.

Koenig, W. W., "Continuous Countercurrent Ion Exchange. I: Resin Particle Settling Rates in Spinner Columns" **(with J. Olin, A. L. Babb, and J. L. McCarthy),** *Chem. Eng. Prog.,* Symposium Series, 50, 14, 103 (1954). EES Reprint No. 90.

———, *Ibid.,* "II: Mass Transfer Rates in Spinner Columns" **(with J. Olin, A. L. Babb, and J. L. McCarthy),** *Chem. Eng. Prog.,* Symposium Series, 50, 14, 111 (1954). EES Reprint No. 91.

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———, "Vapor-Liquid Equilibria of the System Carbon Dioxide-Hydrogen Sulfide-Sodium Carbonate-Sodium Bicarbonate-Sodium Sulfide-Water" **(with A. L. Babb),** *Ind. and Eng. Chem.,* (1955). EES Reprint No. 99.

Markham, A. E., "Equilibrium Distribution of Ammonium and Other Ions Between Cation Exchange Resins and Aqueous Solutions: Sulphite Spent Liquor V" **(with V. F. Felicetta, J. L. McCarthy),** *TAPPI,* Vol. 37, No. 10 (Oct., 1954). EES Reprint No. 88.

McCarthy, J. L., "Equilibrium Distribution of Ammonium and Other Ions Between Cation Exchange Resins and Aqueous Solutions: Sulphite Spent Liquor V" **(with V. F. Felicetta, A. E. Markham),** *TAPPI,* Vol. 37, No. 10 (Oct., 1954). EES Reprint No. 88.

———, "Behavior of Celluloses in Sodium Hydroxide Solutions" **(with O. Anker-Rasch),** *Norsk Industrie,* Oct., 1954. (Reprinted in *The Trend in Engineering,* Vol. 7, No. 3, July, 1955).

———, "Continuous Countercurrent Ion Exchange I: Resin Particle Settling Rates in Spinner Columns" **(with J. Olin, W. W. Koenig, and A. L. Babb),** *Chem. Eng. Prog.,* Symposium Series, 50, 14, 103 (1954). EES Reprint No. 90.

———, *Ibid.,* "II: Mass Transfer Rates in Spinner Columns" **(with W. W. Koenig, J. Olin, and A. L. Babb),** *Chem. Eng. Prog.,* Symposium Series, 50, 14, 111 (1954). EES Reprint No. 91.

———, "Lignin IV. Electrophoresis Study of Alkaline Cleavage Products from Lignin Sulfonates" **(with R. E. Davis, E. T. Reaville, and Q. P. Peniston),** *Jour. Am. Chem. Soc.,* 77, 2405 (1955). EES Reprint No. 96.

———, "Lignin V. Vanilloylformic Acid from Alkaline Cleavage of Lignin Sulfonates" **(with D. W. Glennie, H. Techlenberg, and E. T. Reaville),** *Jour. Am. Chem. Soc.,* 77, 2409 (1955). EES Reprint No. 97.

———, "Lignin VI. Molecular Weight of Lignin Sulfonates by Light Scattering" **(with J. Moacanin, V. F. Felicetta, and W. Haller),** *Jour. Am. Chem. Soc.,* 77, 3470 (1955). EES Reprint No. 98.

Moulton, R. W., "Adsorption of Binary Hydrocarbon Mixtures on Activated Charcoal: Variation of Molecular Weight of Adsorbate" **(with F. Oré),** *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

———, "Factors Affecting Gas Recirculation and Particle Expansion in Spray Drying" **(with J. H. Buckham),** *Chem. Eng. Prog.,* 51, 3 (Mar., 1955).

Olin, J., "Continuous Countercurrent Ion Exchange I: Resin Particle Settling Rates in Spinner Columns" **(with W. W. Koenig, A. L. Babb),** *Chem. Eng. Prog.,* Symposium Series, 50, 14, 103 (1954). EES Reprint No. 90.

———, *Ibid.,* "II: Mass Transfer Rates in Spinner Columns" **(with W. W. Koenig, A. L. Babb),** *Chem. Eng. Prog.,* Symposium Series, 50, 14, 111 (1954). EES Reprint No. 91.

Oré, F., "Adsorption of Binary Hydrocarbon Mixtures on Activated Charcoal: Variation of Molecular Weight of Adsorbate" **(with R. W. Moulton),** *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

PENISTON, Q. P., "Lignin IV. Electrophoresis Study of Alkaline Cleavage Products from Lignin Sulfonates" **(with R. E. Davis, E. T. Reaville, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* **77,** 2205 (1955). EES Reprint No. 96.

REAVILLE, E. T., "Lignin IV. Electrophoresis Study of Alkaline Cleavage Products from Lignin Sulfonates" **(with R. E. Davis, Q. P. Peniston and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* **77,** 2205 (1955). EES Reprint No. 96.

———, "Lignin V. Vanilloylformic Acid from Alkaline Cleavage of Lignin Sulfonates" **(with H. Techlenberg, D. Glennie, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* **77,** 2409 (1955). EES Reprint No. 97.

TECHLENBERG, H., "Lignin V. Vanilloylformic Acid from Alkaline Cleavage of Lignin Sulfonates" **(with D. Glennie, E. T. Reaville, and J. L. McCarthy),** *Jour. Am. Chem. Soc.,* **77,** 2409 (1955). EES Reprint No. 97.

WAMSLEY, W. W., "Fluidized Bed Heat Transfer" **(with L. N. Johanson),** *Chem. Eng. Prog.,* **50,** 347 (1954).

Graduate Theses: 1954-1955

Ph.D. in Chemical Engineering

EES: Engineering Experiment Station Fellow

TAPPI: Technical Association of the Pulp and Paper Industry Research Fellow

CALDWELL, COLIN S.: Interferometric Study of Molecular Diffusion in Binary Liquid Systems. (EES)

HAYDEN, DANIEL T.: Vapor-Liquid Equilibria in the System Ammonia-Sulfur Dioxide-Water. (EES, TAPPI)

HERRMAN, ARTHUR J.: Ion Exchange Resin as a Vapor Phase Catalyst. (EES)

MAI, KLAUS L.: Equilibrium Studies of the System Na_2O-CO_2-H_2S-H_2O. (EES)

M.S. in Chemical Engineering

DC: Dow Chemical Company Fellow

EES: Engineering Experiment Station Fellow

HVT: Herman V. Tartar Fellow

MC: Monsanto Company Fellow

WHD: William H. Dehn Fellow

BENGSTON, KERMIT B.: Further Studies of Olivine Chlorination at High Temperatures. (WHD)

BOLME, DONALD W.: The Effect of Temperature upon Azeotropic Composition. (MC)

BROOKS, BURTON: Kinetics Studies in the Production of Synthetic Detergents.

HARDT, ALEXANDER P.: The Thermodynamics of Irreversible Processes Applied to the Corrosion of Lead in Nitric Acid. (DC)

NAMES, PAUL G.: Preliminary Investigation of Continuous Liquid-Liquid Extraction in a Rotating Disk Column. (MC)

OTTERBEIN, GLENN L.: Self-Diffusion of Methanol in the System of Methanol-Water. (EES)

PIGOTT, GEORGE M.: Iron Sulfide Discoloration of Tuna Fish Cans: Role of Sulfur.

SHAHANI, MOTI J.: Continuous Countercurrent Ion Exclusion.

WETHERN, RICHARD J.: Titanium Metal from Titanium Tetrachloride by Fused Salt Electrolysis. (HVT)

NEW REPRINTS

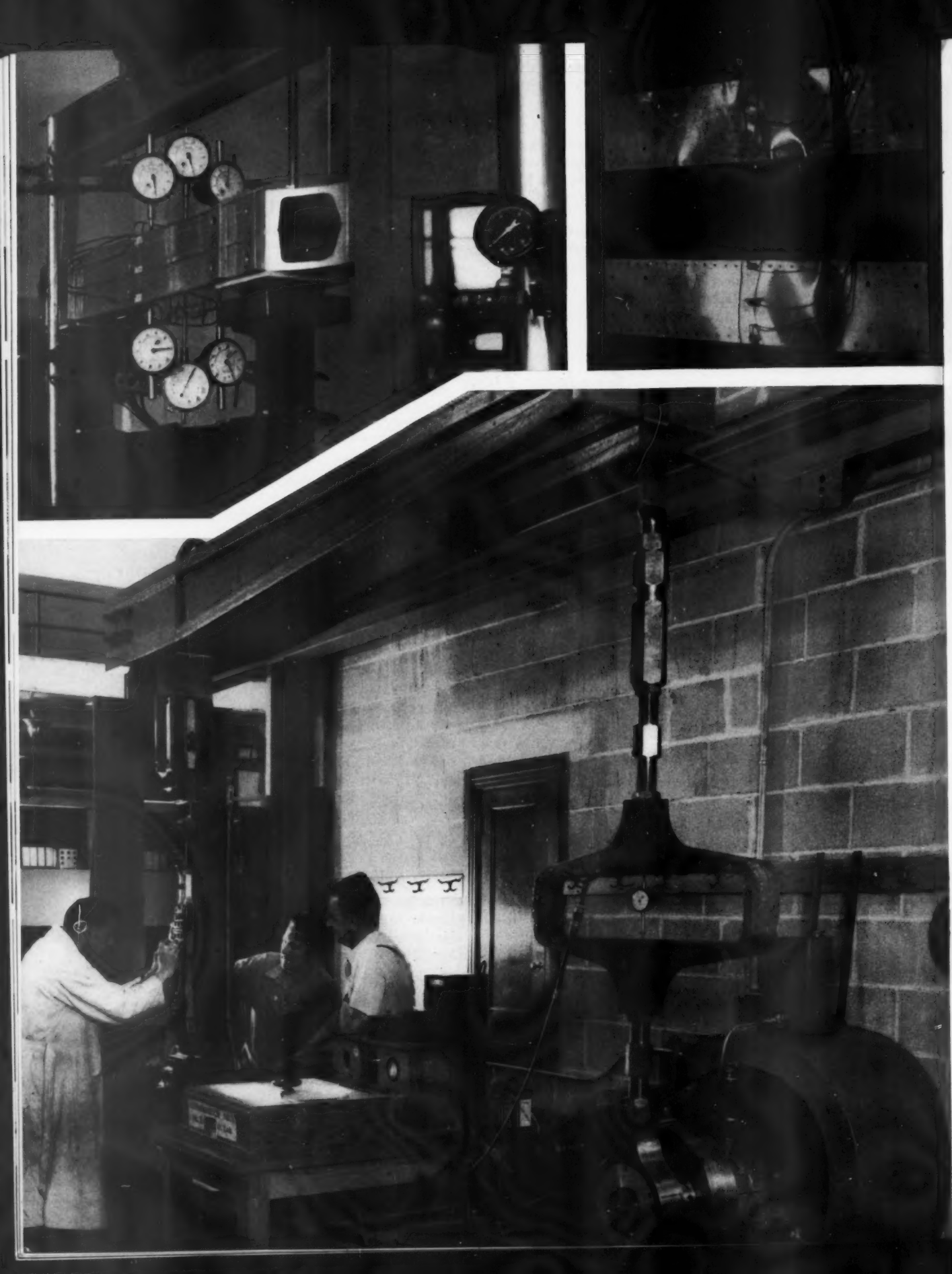
Reprint No. 96. "Lignin IV. Electrophoresis Study of Alkaline Cleavage Products from Lignin Sulfonates." R. E. Davis, E. T. Reaville, Q. P. Peniston, Joseph L. McCarthy, *Jour. Am. Chem. Soc.,* **77,** 2405 (1955).

Reprint No. 97. "Lignin V. Vanilloylformic Acid from Alkaline Cleavage of Lignin Sulfonates." D. W. Glennie, H. Techlenberg, E. T. Reaville, and Joseph L. McCarthy, *Jour. Am. Chem. Soc.,* **77,** 2409 (1955).

Reprint No. 98. "Lignin VI. Molecular Weights of Lignin Sulfonates by Light Scattering." Joseph L. McCarthy, Wolfgang Haller, *Jour. Am. Chem. Soc.,* **77,** 3470 (1955).

Reprint No. 99. "A Critical Appraisal of Sewage Works Operation and Design." Robert O. Sylvester, *Sew. and Indus. Wastes,* Vol. 27, No. 7 (July, 1955).

Reprint No. 100. "Vapor-Liquid Equilibria of the System Carbon Dioxide-Hydrogen Sulfide-Sodium Carbonate-Sodium Sulfide-Water." A. L. Babb, K. L. Mai, *Indus. and Engg. Chem.,* Sept., 1955.



Civil Engineering

R. B. VAN HORN
Executive Officer

R. B. Van Horn

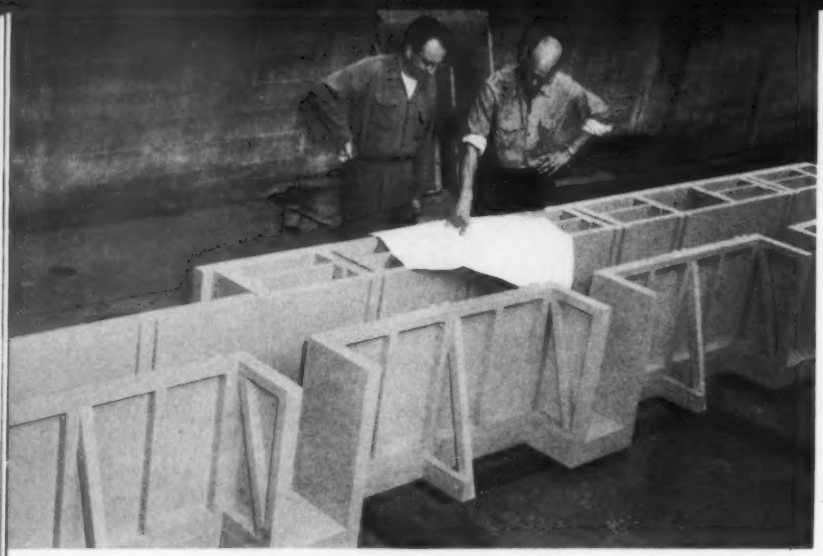
The research program of this department is divided into the following four classifications: (1) sponsored projects, (2) Engineering Experiment Station projects (which are under departmental supervision), (3) departmental projects, and (4) individual faculty research. Space limitations will permit the listing of only those sponsored projects under contract or operating on Letters of Intent.

Three out of the following five major projects have been completed during the period of this report, 1953-1955.

1. Aerodynamic Stability of Suspension Bridges (initiated in 1941). Sponsored by the U. S. Bureau of Public Roads, the Washington Toll Bridge Authority, and the University of Washington. Supervisor: Professor F. B. Farquharson, with Professor F. C. Smith and George S. Vincent, Bridge Engineer, U.S.B.P.R., assisting. Publication of Parts IV and V of Bulletin No. 116 by the Engineering Experiment Station completed the report in June, 1954.
2. Reinforcement of Openings in Structural Members by Welding. Sponsored by the Bureau of Ships, Navy Department. Supervisor: Dr. R. A. Hechtman, with Dr. Desi D. Vasarhelyi as Research Engineer. Forty-one large plate specimens were tested at room temperature and at temperatures to –40° F. Final report was submitted in March, 1955.
3. Slip of Structural Steel Double Lap Joints Assembled with High-Strength Bolts. Sponsored by the Research Council on Riveted and Bolted Structural Joints. Supervisor: Dr. R. A. Hechtman. Results of these tests to date have been published as ASCE Separate No. 484.
4. Long-Range Stream-Flow Forecasting for the Columbia Basin. A joint project with the Department of Meteorology and Climatology. Sponsored by the Bonneville Power Administration. Supervisors: Professor T. H. Campbell of the Civil Engineering Department and Dr. Phil E. Church of the Department of Meteorology.
5. Another major project still in operation began shortly after June, 1951, when the Washington State Council for Highway Research was established by the Governor of the State. This Council consists of the Chairman of the State Highway Commission, the Director of Highways, a Professor of Civil Engineering from both the University of Washington and Washington State College, the District Engineer of the Bureau of Public Roads, and representatives from the Association of Washington Cities, Association of County Commissioners and the Washington Highway Users Conference. Professor R. G. Hennes of this Department has served as Chairman since the organization of the Council, as well as director of the highway research work which has been done at the University of Washington. The University and Washington State College, have been used by the Council as research agencies for the majority of their projects. Projects carried on during the past two years include:

1. Application of WASHO Test Data to Washington Roads. Requested by the Highway Users Conference and subsequently included in the Highway Cost Allocation Project. Assigned to the University of Washington.
2. County Road Needs (Gas Tax Allocation). Requested by the Legislature Fact-Finding Committee on Highways, Streets and Bridges to study the allocation of the counties' share of the state-collected motor-fuel taxes among the several counties in Washington. Begun in October, 1954, it is a joint project of the University of Washington and Washington State College.
3. Highway Cost Allocation Project. A study of "motor vehicle taxation including the assignment of total costs among property owners, general taxpayers and highway users." Requested by the Legislative Interim Committee on Highways, Streets, and Bridges, and assigned to the University, it began in October, 1953, and will be completed by June 1, 1956. Major sub-studies include the effect of road improvement on urban property values, rural property

OPPOSITE PAGE: *(Upper left)* **Test of model box beam;** *(right)* **buckled compression plates of box beams;** *(below, l. to r.)* **HERB MYRIE of the Boeing Airplane Co., JOE MCCLELLAND, EES machinist, Dr. D. D. VASARHELYI, supervisor of the Structural Research Laboratory, conducting fatigue test.**



LEFT

Dr. E. P. RICHEY *(right)* and Professor H. H. CHENOWETH are looking over the power-house section of the Mayfield dam model which is to be used to study fish facilities of the dam.

BELOW

Graduate student from the Department of Fisheries is observing the flow of bentonite particles through model baffles of the Hell's Gate fishway, in the Hydraulic Laboratory.

BELOW

Highway Research Staff. Professor R. G. HENNES, project supervisor, at extreme left. WILLA MYLROIE, research assistant professor, at corner of table. Besides Engineering, the staff represents Business Administration, Economics, Planning, Geography, and Mathematics.

values and commercial users of highways; historical development of road standards and financing; road costs, and the evaluation of various road taxing theories as applicable to the 59,000 miles of Washington roads and streets.

These highway research projects, and the two other completed in January, 1953, and reported previously, have been under the direct supervision of Willa Mylroie, Research Assistant Professor and Executive Secretary of the Council. They have helped not only those desiring answers to highway transportation problems but also many students, both financially and research-wise, during the four years this program has been in existence. From June, 1951, to June, 1955, this program has employed 11 undergraduate students, 36 graduate students, five full-time research personnel, and ten University faculty members on a part-time basis, for periods of time ranging from three months to two years. These students and faculty have come from the fields of Engineering, Geography, Economics, Business Administration, Planning, Sociology, Meteorology, and Mathematics. Four graduate theses have been based in whole or in part on these research studies.

In addition to these major projects, a number of projects of somewhat lesser magnitude have included the following:

1. Lateral Buckling of Rolled Steel Beams Under Transverse Loading. Sponsored by the Column Research Council. Supervisor: R. A. Hechtman. Simply supported beams 10 inches to 18 inches in depth were tested. Final report, June, 1954.
2. Aerodynamic Investigation of the Mackinac Straits Bridge. Sponsored by Dr. D. B. Steinman, Consulting Engineer. Supervisor: Professor F. B. Farquharson. Completed May, 1955.
3. Vibration of Overhead Conductors Under Wind Action. Sponsored by the Aluminum Company of America. Supervisor: Professor F. B. Farquharson. Completed April, 1954.
4. Fatigue Tests for the Boeing Airplane Co. Supervisor: Dr. Desi D. Vasarhelyi.
5. Properties of Heavy Aggregate Concrete. Sponsored by the General Electric Co. Hanford Project. Supervisor: Professor H. P. Mittet. Completed January, 1954.
6. Investigation of the Quality of Water of the Columbia River and Effect on the Fisheries Resource. Sponsored by the U. S. Fish and Wildlife Service. Project administration is under the School of Fisheries. The Quality Survey is being supervised by Professor R. O. Sylvester, assisted by Professor H. P. Mittet.
7. Model Study of the Fish Facilities of the Mayfield Dam. Sponsored by the City of Tacoma, Light Division. Supervisor: Dr. E. P. Richey. The models for this project are being built by the City of Tacoma. Tests are run in the Hydraulic Laboratory.

Publications: 1954-1955

Books

EKSE, M. I., *Fundamentals of Transportation Engineering* **(with R. G. Hennes),** McGraw-Hill Book Co., Inc., 1955.

HENNES, R. G., *Fundamentals of Transportation Engineering* **(with M. I. Ekse),** McGraw-Hill Book Co., Inc., 1955.

Technical Articles

BOGAN, R. H., "Synthetic Detergents," Reports on Research, M.I.T., Vol. 5, No. 6 (1954).

———, "Biochemical Degradation of Synthetic Detergents" **(with C. N. Sawyer),** "I: Preliminary Studies," *Sew. and Ind. Wastes,* Vol. 26, p. 1069 (1954).

———, *Ibid.,* "II: Studies on the Retention Between Chemical Structure and Biochemical Oxidation," *Sew. and Ind. Wastes,* Vol. 27 (1955).

———, "Biochemical Oxidation of Synthetic Detergents" **(with C. N. Sawyer),** *Proceed.,* 10th Purdue Uni. Indus. Waste Conf., 1955.

CAMPBELL, T. H., "Water Hammer, Resonance and Impedance in Liquid Filled Pipes," Boeing Airplane Co. Document, Sept., 1954.

———, "Let's Look at Engineering Education," *The Trend in Engineering,* Vol. 7, No. 3 (July, 1955).

CHIN, A. G., "Slip of Joints Under Static Loads" **(with R. A. Hechtman, D. R. Young, and E. R. Savikko),** ASCE *Proceed.,* Separate No. 484, Sept., 1954.

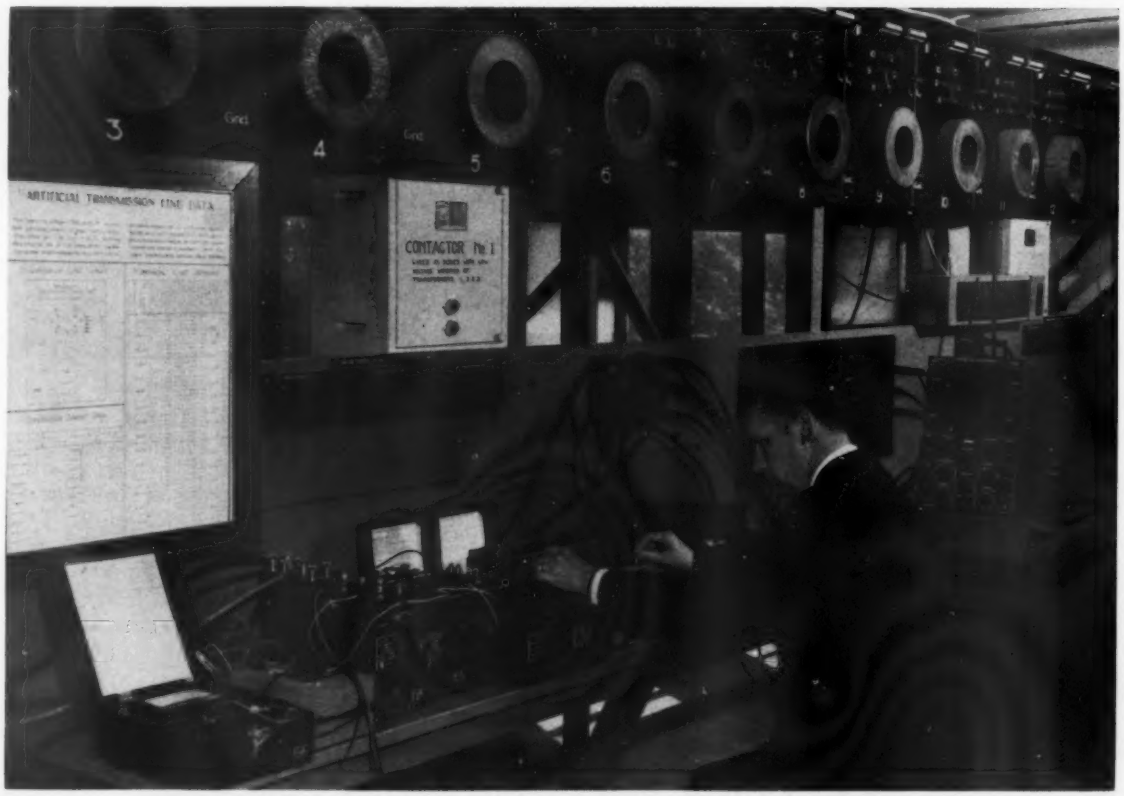
FARQUHARSON, F. B., "The Vibration of Steel Stacks" **(Walter L. Dickey and Glenn B. Woodruff).** Discussion, *Proceed.,* ASCE, Vol. 81, Separate No. 661 (1955).

HECHTMAN, R. A., "Slip of Joints Under Static Loads" **(with D. R. Young, A. G. Chin, and E. R. Savikko),** ASCE *Proceed.,* Separate No. 484, Sept., 1954.

———, "Final Report on Welded Reinforcement of Openings in Structural Steel Tension Members"

(Continued on page 35)

Dr. G. HELD *(right)* and Mr. G. HASSERDJIAN with the experimental setup of slots on a cone.



Professor F. R. BERGSETH with experimental layout of transistorized transmission-line relay.

Electrical Engineering

AUSTIN V. EASTMAN
Executive Officer

Austin V. Eastman

The development of the research program in the Department of Electrical Engineering since the last report (in 1953) has kept pace with the expansion of the graduate teaching program, both master and doctoral. A large percentage of graduate students in the Department, in addition to preparing theses, are employed on research projects, sponsored either by the Engineering Experiment Station or by government or industry. A brief summary of these activities is given in the following paragraphs.

The heat-pump work of Professor George Smith has created a great deal of interest, not only in local circles, but throughout the country. In particular he has obtained data which will assist people in avoiding some of the mistakes of earlier installations, such as attempting to use ground grids to obtain the source of heat in city lots with insufficient area. Such publications as have been issued throughout the past several years have been in such demand that they have gone out of print in a short time, and he is now preparing an Engineering Experiment Station bulletin summarizing the work presented in previous publications and adding some new material.

Dr. L. J. Lewis is in charge of a new research program sponsored by Seattle City Light. For many years network analyzers have been used to solve problems posed by the operation of large power systems, such as the Northwest Power Pool, but they fail to provide all the information necessary to operate such systems with maximum efficiency and reliability. As one example, power utilities must know how to use their water storage most effectively if they are to obtain the maximum possible output from the system. Indications are that some of the recently developed electronic computers may be able to provide this sort of information as well as to solve other problems which the analyzer is inadequate to meet, or to provide more complete information on problems the solutions of which have previously been found with the aid of analyzers. The present study will attempt to determine some of the possibilities and limitations of computers used for this purpose, with the aid of the University's IBM computer. Dr. David Johnson, a newly appointed assistant professor in the Department, will work with Dr. Lewis.

Professor F. R. Bergseth is continuing his research on power relaying problems, under the sponsorship of Bonneville Power Administration. This work is proving of value in helping to assure continuous operation of the power networks of the Northwest, since the results of this research, when applied to the power system of BPA, permit the clearing of faulted lines without causing a widespread power failure.

Dr. Gedaliahu Held, appointed as assistant professor in this Department last fall, is in charge of an investigation of microwave antenna systems and other related problems, under a contract negotiated with the U. S. Air Force. In particular he will study the performance of cone antennas and other similar arrangements, suitable for mounting on modern jet planes without seriously increasing wind resistance. Dr. Held has already gained a national reputation in this field, having published several papers before coming to the University of Washington. He will be assisted by Mr. Gerard Hasserdjian, an instructor in the department, and by one or more graduate students.

Dr. James Fisher has carried on research on electrical flowmeters, by means of which the flow of fluids in pipes or other containers can be accurately measured. This program has been of interest to aircraft companies, as well as others, and Dr. Fisher spent last summer with a firm in Los Angeles which is doing a large amount of research and development work for aircraft companies. He is also working closely with the Boeing Aircraft Company and we hope to create a program of mutual interest in this field of research.

The work of Professor Myron Swarm in the field of radio propagation has been carried on by Professor Lyall Cochran during Professor Swarm's absence during the past year. In particular the field strength of a Portland VHF station has been continuously recorded and attempts will be made to correct these data with weather data for the same period of time. This is a long-range project, results from which will be obtainable only after a large amount of computation, perhaps with the aid of the University's IBM computer. Professor Swarm has spent the past year at Stanford carrying on research and study in this field toward the Ph.D. degree and will provide

impetus to this important project when he returns next January.

Professor Walter Rogers has developed some new lighting techniques which will enable a rubber membrane to be used quantitatively as an analog computer in the study of electric fields. He reported this research in an invited paper presented before the New York Academy of Sciences.

Other studies conducted by members of the Department include work on a mechanical language translator under the supervision of Professor Hill and Mr. Wall, which will do more than a word-for-word translation, as it will attempt to take into account the meaning of groups of words where it is different from a word-to-word translation. Professor Hoard continues to work with the Department of Fisheries on the problem of electrically guiding fish around dams and turbines, through fish ladders. Professor Robbins has made a study of the possible use of steam plants in the Pacific Northwest to help relieve the power shortage experienced each year.

Research activity in this department is increasing rapidly. Starting July 1, 1955, five or six staff members will devote half of their time to doing research under sponsorship of various government or municipal agencies throughout the academic year and full time during the summer. There will be six or seven doctoral candidates, most of whom will be engaged in research under one of the programs listed in this report. In addition eight to ten graduate students out of some thirty-five working for their Master's degree, will be active in less extensive programs sponsored by the Engineering Experiment Station.

Publications: 1954-55

Technical Articles

Fisher, J. H., "Electromagnetic Flowmeter Design and Performance," *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

Harrison, A. E., "A Method of Forming a Broad-Band Microwave Frequency Spectrum" **(with R. E. Wall, Jr.),** *Transactions,* IRE Professional Group on Microwave Theory and Techniques, Jan. 1955. EES Reprint No. 93.

———, "Glaciers Reflect Our Changing Climate" **(with K. B. Bengtson),** *Mountaineer,* Dec., 1954.

———, "Fluctuations of the Nisqually Glacier, Mt. Rainier, Washington, During the Last Two Centuries," *Journal,* Internat. Assoc. of Hydrology, 1955.

Held, G., "Interaction Between Wide Slot Radiators" **(with H. Unz, D. J. Angelakos),** IRE NC Rep. No. 121, Ser. 60 (Oct. 30, 1954).

———, "Studies of the Diffraction of E.M. Waves by Circular Apertures" **(with M. Ehrlich, S. Silver),** *Jour. App. Phys.,* Mar., 1955.

Hoard, G. L., "Factors in Pulsated Direct Current which Cause Electrotaxis and Side Effects in Young Salmon" **(with E. Aserinsky, R. E. Nakatani, and L. Verhoeven),** School of Fisheries, Uni. of Wash., Technical Report No. 5 (1954).

Lewis, L. J., "Power System Analysis: A Problem of Dynamics," *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

———, "Harmonic Analysis for Nonlinear Characteristics," AIEE *Communication and Electronics,* Jan., 1955. EES Reprint No. 92.

Robbins, F. D., "Ultramodern Steam Plants for the Pacific Northwest Power System," *The Trend in Engineering,* Vol. 7, No. 3 (July, 1955).

Rogers, W. E., "Design and Application of Membrane Analogs," *Annals,* N. Y. Acad. Sci., Apr. 30, 1955. EES Reprint No. 95.

Smith, G. S., "Heat Pump Used in Sewage Digestion," *Elect. World,* Apr. 4, 1955.

Wall, R. E., Jr., "A Method of Forming a Broad-Band Microwave Frequency Spectrum" **(with A. E. Harrison),** *Transactions,* IRE Professional Group on Microwave Theory and Techniques, Jan., 1955. EES Reprint No. 93.

Graduate Theses: 1954-55

M.S. in Electrical Engineering

EES: Engineering Experiment Station Fellow

Arya, Michael G.: Polarization in the AC Electromagnetic Flowmeter. (EES)

Perry, Fred E.: Some Considerations in the Design of a Transistor Clipper-Amplifier for Use at Audio Frequencies.

Sutherland, Louis C.: A Study of the Ground Coil as a Heat Source for Heat Pumps.

Williams, Albert F.: The A-C Voltage Comparator.

Mechanical Engineering

B. T. McMinn
Executive Officer

B. T. McMinn

A few current research projects in mechanical engineering, which have evoked widespread interest, are reviewed briefly here.

A triaxial-stress study of rubber and neoprene gland seals for severe service, made under the direction of Professor James B. Morrison, has uncovered some unexpected relationships which are expected to rationalize design procedure and materially reduce the complexity of the gland itself.

The free-piston engine project, which has been underway for some years, has proceeded through one working model to a second, involving a nonmechanical method of synchronizing the opposed parts. This modification, if it proves successful, will be a milestone in the development of this type of prime mover. This project is under the guidance of Professor William B. Nordquist.

Following preliminary studies by Dr. T. G. Thompson, Professor of Oceanography, experimental work is underway on developing processes for desalting of sea water by freezing, in a project under the joint direction of Dr. R. W. Moulton of Chemical Engineering and Professor H. M. Hendrickson. The current attack is concerned with a combination of freezing and centrifuging in a continuous process, and results so far are very encouraging. This project is sponsored by the United States Department of the Interior, and the studies at the University are part of a large national program in which this important problem is under attack from many angles.

Apparatus has recently been completed and put into service for making comparative studies of solar heat collection by the standard pyrheliometer, flat-plate, and parabolic-trough collectors, both of the latter in three orientations: normal to zenith, normal to noon position, and tracking. One outcome of this work is expected to be a useful conclusion regarding cost-vs-return for the involved mechanism required for tracking. This work is under the direction of Professor Richard W. Crain.

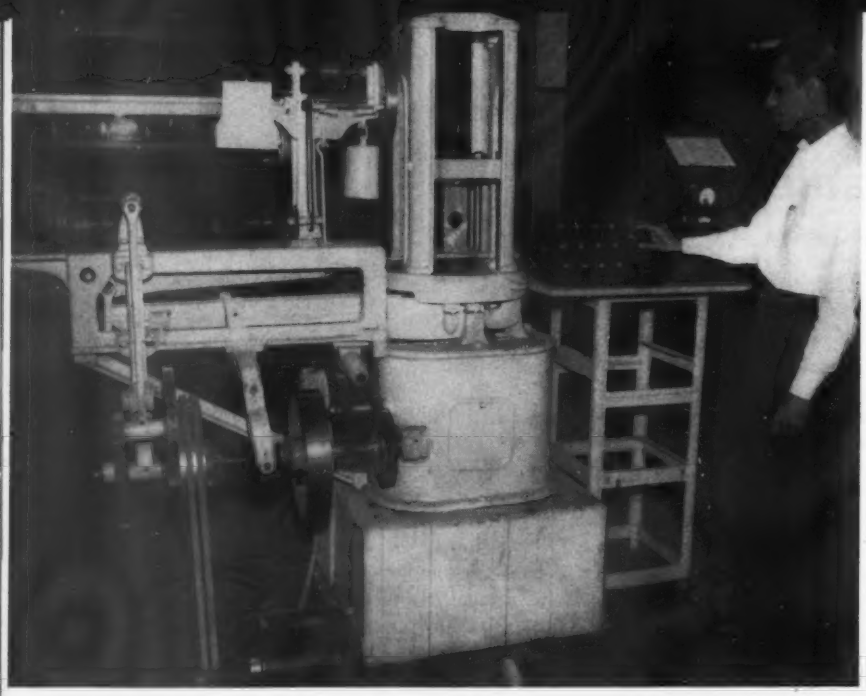
Apparatus to study and demonstrate the three modes of process control, singularly and in combinations, with pneumatic and hydraulic actuation, has been constructed under the direction of Professor Peter L. Balise. This breadboard type of apparatus can be quickly set up to vividly show the effects of various combinations on the control function and the desirable limits of each type of control for a given system. Plans are proceeding for purely mechanical and electrical analogs covering the same ground.

The exact conditions existing during the period of combustion in an internal-combustion engine have never been determined, either in theory or experimentally, and as a result conflicting theories are current as to the nature of detonation and knock, which are apparently the cause of much poor performance. Professor J. C. Firey is conducting exploratory experiments looking to the development of a modified test cylinder incorporating a device which will delineate the actual waves propagated during combustion.

Work on the various phases in the utilization of olivine as a foundry molding material is continuing under the guidance of Professors Gilbert S. Schaller and William A. Snyder. Papers given to date have elicited correspondence from all parts of the world, indicating the timeliness and importance of this work. This project is of particular interest economically, as the State of Washington contains a substantial part of the known deposits of olivine in the United States.

Some twenty curriculum changes have been made in the Department of Mechanical Engineering in the last two years, most of them reflecting the current emphasis on scientific core and creative thinking. (See ASEE "Evaluation" report.) *Dynamics of Machines,* open to seniors and graduates, is typical of the new courses. Its catalog description (acceleration effects in machine design; equation of motion with variable mass and friction forces; elementary vibration theory; gyroscopic effects in machinery; flexible machine members in motion) gives an inkling of its purpose, which is to demonstrate to the student the unity in the fundamental thinking which he has had badly fragmentized under course titles such as physics, statics, dynamics, mechanisms, machine design, materials, etc., and to encourage originality in the approach to engineering problems.

A graduate course of similar intent is *Mechanical Engineering Analysis.* This course is essentially an exploration into a wide variety of engineering problems to establish their common ground, of either the same or analogous theory, and then proceeds to appropriate mathematical solutions, taking full advantage of analogies.



Left Above

R. K. Chakrabarti, EES research assistant in Mechanical Engineering, determining stress concentration in metal member under compression.

Left Below

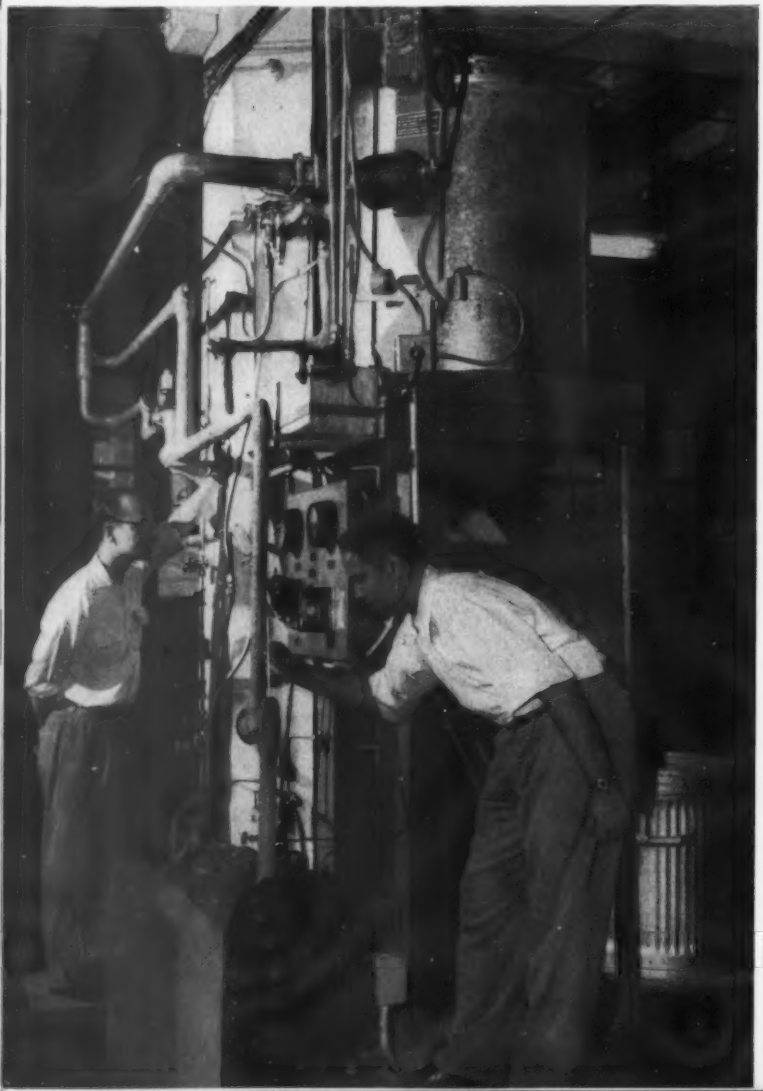
K. V. Ly *(left)* and G. C. Motwani, research assistants in Mechanical Engineering, with ice-making equipment for the desalting project.

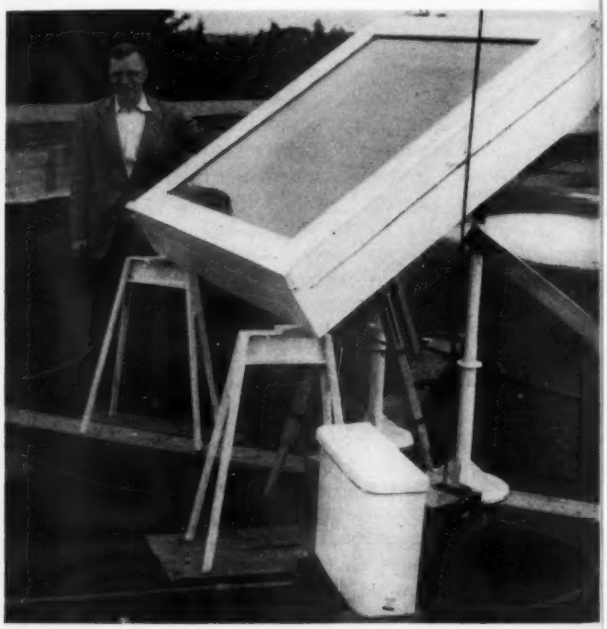
Right Center

Brad O. Reese, EES research assistant in Mechanical Engineering, with solar energy collector apparatus.

Right Below

Pyrheliometer of the Department of Meteorology used also in the solar heat project for comparison of data.





Publications: 1954-1955

Technical Articles

BALISE, P. L., "Effects of System Components in Process Control," *The Trend in Engineering,* Vol. 7, No. 2 (Apr., 1955).

———, "Realistic Spur Gear Design," *Mach. Des. & Mftg. Bull.,* ASEE, Mar., 1955.

CHILDS, M. E., "A Theory for Base Pressures in Transonic and Supersonic Flow" **(with H. H. Korst, R. H. Page),** Uni. Ill. EES, M.E. Tech. Note 392-2 (Mar., 1955).

———, "Compressible Two-Dimensional Jet Mixing at Constant Pressure: Tables of Auxiliary Functions for Fully Developed Mixing Profiles" **(with H. H. Korst, R. H. Page),** Uni. Ill. EES, M.E. Tech. Note 392–3 (Apr., 1955).

DAY, E. E., "Strain Energy Release Rate for Some Perforated Structural Members," *Weld. Jour. Research Supplement,* 1955.

———, (Ed.) *Machine Design and Manufacturing,* Bull. ASEE Machine Design Subdivision, 1953–56.

HENDRICKSON, H. M., "Air Washer Performance," *Heat. & Vent.,* Vol. 50, No. 7 (July, 1953).

———, "How to Calculate Air Washer Performance When Cooling," *Heat., Pip. & Air Cond.,* Vol. 26, No. 9 (Sept., 1954).

———, "Air Conditioning Calculations," Chap. 15, *ASRE Data Book: Design,* 8th ed. (1953–54).

———, "Fishing Boats," *ASRE Data Book: Applications,* 5th ed. (1954–55).

———, (Editor-in-chief) *ASRE Air Conditioning and Refrigerating Data Book: Applications,* 5th ed. (1954–55).

MILLS, B. D., JR., "Mechanical Models as Teaching Aids," *Wash. Engineer,* May, 1955.

OWENS, B. W., "Work Sampling," *Proceed.,* AIIE, 1955.

Graduate Theses: 1954-1955

M.S. in Mechanical Engineering

EES: Engineering Experiment Station Fellow

CRAIN, RICHARD W., JR.: A Solar Radiation Apparatus by Richard Willson Crain, Jr. and Gordon Allan Vincent. (EES)

HAMMOND, MILTON B., JR.: Compressible Fluid Pressure Drop Testing Using Flow Tubes.

HONSBERGER, BRUCE A.: Theory of a Guarded Hot Box with Present and Suggested Future Improvements. (EES)

LEUBA, RICHARD J.: A Liquid Level Analog for the Demonstration of Automatic Control Principles.

O'BRIEN, JAMES R.: Design and Tests of a Supersonic Air Inlet for an Air Breathing Engine.

SHAW, HORACE K.: An Investigation of Theory and Practice of Resistance Wire Strain Gages. (EES)

VINCENT, GORDON A.: A Solar Radiation Apparatus by Richard Willson Crain, Jr. and Gordon Allan Vincent. (EES)

WATSON, WARREN K.: Design and Construction of a Thermal Conductivity Test Apparatus.

Engineering Research Dividends

Recent theses submitted for advanced degrees from the College of Engineering, University of Washington, will regularly appear in abstract form in *The Trend.* Complete copies of these theses are available for reference at the University of Washington Library. Address inquiries to the Director of the Engineering Experiment Station, University of Washington, Seattle 5.

McCOY, E. E., "The Effect of Drainage in Landslide Control." M.S. in Civil Engineering, 1955.

A study of several slides in the Pacific Northwest was made during the year in connection with an Engineering Experiment Station project. With this background and the aid of the literature available, the writer has described the effect of the various water conditions upon slopes and the methods of achieving stable slopes by drainage.

In order to show graphically the effect of drainage upon slope stability, computations were made for an ideal homogeneous material having both cohesion and internal friction. Values of Taylor's stability number were calculated for several slopes and friction angles and presented graphically for different water-table heights. To extend the graphical illustration, stability numbers were also obtained for a clay slope underlain by a sand stratum and plotted against slope angle for different piezometric heads. The graphs show an increase in stability whenever the water table is lowered and may be used to estimate the effect of drainage upon actual slopes, with the proper consideration of the differences between the actual slopes and the ideal cases evaluated in this paper.

Clockwise from upper left: Ceramic engineering student making particle-size determination of clay specimen; J. E. SHOFFNER, instructor, using Norelco X-ray diffract on unit; students standardizing thermocouple for pyrometry; Dr. J. I. MUELLER *(right)* and student with laboratory continuous tunnel kiln; F. SIMPSON, graduate student, using Beckman spectrophotometer with flame-analysis unit.

School of Mineral Engineering

DRURY A. PIFER
Director

Drury A Pifer

Manpower, in adequate numbers and adequately trained, is an outstanding problem of the mineral industry. Mines, metallurgical plants, ceramics producers, metallic product manufacturers, all look to the mineral engineering schools to meet this need. The training of students for advanced work in these diverse fields is the primary object of the graduate research programs in the School of Mineral Engineering. Development of state resources and the consequent creation of new wealth is an important by-product of those programs.

Through a fortunate and successful co-operative agreement between the University and the U. S. Department of the Interior, the Northwest Experiment Station of the Bureau of Mines works closely with the School of Mineral Engineering on mineral industry research. The Bureau's staff of engineers, headed by Dr. H. F. Yancey, supervise much of the graduate work in mineral beneficiation and coal preparation. The University maintains a series of fellowships for this purpose and it may be safely said that the money so invested has been returned to the State many times over in terms of additional mineral recovery and economic savings through better processing. Characteristic of the problems being investigated is the study of refractories made from chromites of the Northwest. A number of deposits of this mineral are known and their exploitation depends upon development of uses other than the recovery of metallic chromium. This problem has been under attack for over ten years with very promising results. Currently the Bethlehem Pacific Steel Company is co-operating in a program of service tests in open-hearth furnaces.

The Ceramic Engineering Division over the past two years has pointed its research work at industrial problems as well as those of a fundamental nature in order to make available to its researchers as well-rounded a program as possible.

Two sponsored research projects took up the bulk of the work on industrial problems. One, sponsored by the Edward Orton Ceramic Foundation, has, over two years, investigated the application of fluid mechanics to the stiff mud extrusion of clays. This forming method is commonly used in the manufacture of structural clay products, sewer pipe, and many types of refractories. One important point made as a result of this work is that, for the first time, a satisfactory method has been used to determine the force necessary to extrude the clay through a die. Another project sponsored by Gladding, McBean & Co., was to determine the action of the attack of molten iron on fire clay refractories, and although a great deal of work has been done in measuring the chemical attack on refractories, most of it has dealt with studying the effect of slags rather than metals.

Ceramic coatings for light metals have become more important in recent years, and research was continued on studying more suitable methods for coating aluminum. Also, some work has been completed to find methods of applying ceramic coatings to the new "wonder metal," titanium.

The X-ray investigation of ceramic materials has continued, and a new high-temperature furnace has been designed and constructed enabling the X-ray laboratory to study reactions and reaction rates at elevated temperatures. It is contemplated that this will open new fields of study for this investigative tool. Pioneering work in the development of methods to analyze light elements by means of X-ray fluorescent spectrography resulted in the development of commercial equipment for this purpose.

Co-operating with the School of Dentistry, research has been carried on for several years in attempting to improve the materials used in dental porcelains and to make fundamental studies of commercial porcelains and their final constitution after firing.

A model tunnel kiln utilizing electrical resistors as a source of energy was built by personnel in the Ceramic Engineering Division, and a series of tests have been under way for the past year to determine the economic feasibility of using this source of energy in firing ceramic products.

Co-operative work with the Northwest Experiment Station laboratories included studies concerned with determination of optimum firing temperature ranges and the characteristics of the resultant products obtained from high-firing clays of eastern Washington.

Also, the bentonite deposits of the Tieton area have received attention. Bentonite clays are used as bleaching agents in oil refining, and some types have been used as an inexpensive, long-lived lining in irrigation canals. A complete knowledge of the

LEFT

W. E. ANDERSON, aeronautical engineer and graduate student in Metallurgy, taking a photomicrograph of a polished metal test specimen (metallograph).

physical properties of the mineral from each deposit is essential to a successful commercial application.

The rapidly expanding metallurgical industry in the Northwest is adding to the diversity of job opportunity in this region. Processing plants are added as rapidly as the energy base expands to supply the needed power. Metal manufacture, requiring trained metallurgists at every stage of the operation, is developing. Metallurgists are keymen in both production and application of atomic energy. The Division of Metallurgy is meeting these needs by a strong graduate training program. Metallurgical research tends to be on the scientific side with details and manner of practical application left to industry. Current research in physical metallurgy is in the fields of plastic deformation, corrosion, effects of supersonic vibration, dilation of construction steel, and properties of high-purity aluminum.

The corrosion study has been made on stainless steels, a material used in many conditions of severe service in which corrosion is critical. During the past year it was discovered that corrosion resistance can be improved by preparation involving controlled conditions of temperature combined with strain. A study is also under way on the corrosion resistance of stainless-steel powder compacts.

The technique of straightening deformed construction steel by heating at selected points has been perfected industrially. A current investigation is concerned with the fundamental metallurgy of this method.

The heavy-media process as applied to coal cleaning continues under investigation. Accurate control of the media density is a critical factor in operation. Research continues on aspects of this problem. This year a detailed comparison was made of several methods for measuring the viscosity of mineral suspensions. Such information may lead to the design of more efficient control equipment and in turn enable lower grade materials to be profitably mined or to improve recovery from ores now being concentrated.

Industrial developments pioneered in the School of Mineral Engineering and Northwest Experiment Station laboratories continue to find application. Interest continues in the results of the state-wide survey for raw material for an expanded light-weight concrete aggregate and in the pilot-plant tests made on the suitable materials. The 'cyclone' used for both classifying and thickening mineral pulps is being introduced into almost every mill in the country. Improvements in techniques of coal and mineral preparation have been rapidly accepted by industry.

Publications: 1954-55

Technical Articles

MUELLER, E. E., "New Trends in Ceramics **(with J. I. Mueller),** *Engin. Digest,* Feb., 1955. (Reprinted from *The Trend in Engineering,* 1954.)

———, "Ceramic Educational Council Activities," *Ceramic Age,* 64 (1) 20 (1954).

———, "Ceramic Engineering: University of Washington," *ibid.,* 36–38.

———, "Seek Answer to Low Enrollment in Ceramic Schools," *Bull. Am. Cer. Soc.,* 33 (8) 254 (1954).

———, "The Northwest Ceramic Industries," *Pac. Coast Cer. News,* IV, (5) 23–24 (1955).

MUELLER, J. I., "New Trends in Ceramics" **(with E. E. Mueller),** *Engin. Digest,* Feb., 1955. (Reprinted from *The Trend in Engineering,* 1954.)

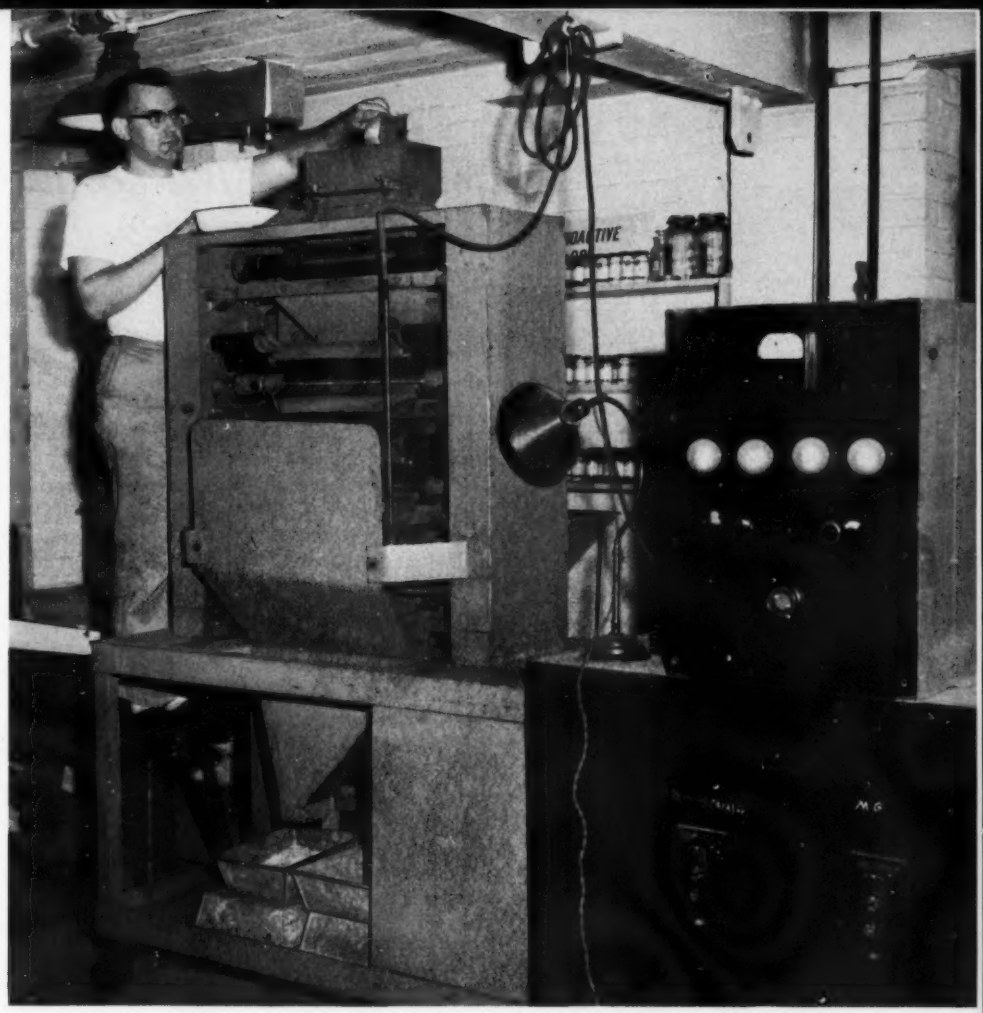
———, "Analytical Aspects of X-Ray Diffraction," *Norelco Reporter,* Vol. 2, No. 1 (Jan. Feb., 1955.) (Reprinted from *The Trend in Engineering,* 1954.)

———, (Ed.) *Explore a World of Ceramics,* Vocational Brochure, American Ceramic Society, 1955.

———, "Porcelain Enamels for Aluminum," *The Trend in Engineering,* Vol. 7, No. 2 (Apr., 1955).

RIGHT

H. W. SORSTOKKE, student in mineral dressing, testing mineral separation by the electrostatic concentrator. By this process, iron minerals, for example, can be separated from glass sands. The sample is fed through the hopper and passes through an electric field, the different degrees of conductance of the minerals making the separation possible.



PIFER, D. A., "Washington's Mineral Industries," *Puget Sound Eng. Bull.,* May, 1955.

ROBERTS, E. C., "Chromium Distribution Between Liquid Iron and Molten Basic Slags" **(with N. J. Grant, J. Chipman),** *Trans.,* AIME, **200** (1954).

———, "Creep-Tempering Relationships in Hardened 4.5 Percent Chromium Steels" **(with N. J. Grant, M. Cohen),** *Trans.,* ASM, **47** (1955).

Graduate Theses: 1954-1955

EES: Engineering Experiment Station Fellow

M.S. in Ceramic Engineering

BRADLEY, FENNIMORE N.: The Thermal Shock Resistance of Some Clay-Olivine Bodies.

BURROWS, FREMONT O.: Application of Fluid Mechanics to the Stiff Mud Extrusion Process.

MARSHALL, NISSIM J.: A Study of the Fundamental Properties of Puget Sound Glacial Clays. (EES)

SASTRY, BOMMAKANTI S. R.: X-Ray Diffraction Intensities of Alpha-Quartz. (EES)

M.S. in Metallurgical Engineering

WEBER, JAMES W.: Influence of Ultrasonics on Age Hardening. (EES)

REPRINTS OF ARTICLE ON ULTRAMODERN STEAM PLANTS

The widespread interest aroused by Professor Robbins' article, in the July issue of *The Trend,* on "Ultramodern Steam Plants for the Northwest Power System," was anticipated by the Department of Electrical Engineering which has provided a limited number of reprints for distribution. These may be ordered from

The Department of Electrical Engineering
Room 201, E. E. Building
University of Washington
Seattle 5, Washington

The cost is 25 cents per copy.

Atomic Power: 1945-1955-1965?

(Continued from page 7)

closely for the past five years with representatives of the AEC and its prime contractors in stimulating nuclear engineering programs at various schools. These programs were handicapped initially, however, (1) by the lack of declassified information, (2) by the lack of trained teachers, and (3) by the lack of experimental facilities. The first obstacle is now largely overcome. The volume of declassified material has reached enormous proportions and new knowledge is continually being released.

But there is still a serious shortage of engineering teachers with experience in nuclear technology. Moreover, *adequate* experimental facilities are virtually non-existent at the engineering schools.

More teachers should be given temporary leave by universities to undertake training at the AEC schools at Argonne and Oak Ridge. More opportunities should be provided by the AEC and its prime contractors to employ engineering teachers on a short-term basis at atomic project centers. Every major engineering school in America already has staff experts in such fields as heat transfer, instrumentation, electronics, chemical processing, power-plant design, metallurgy, sanitary engineering, etc. But these experts need additional training in nuclear technology in order to discharge effectively their future responsibilities.

A number of engineering schools have small "hot" laboratories for research with radioactive materials. Several universities have low-capacity research reactors. But these facilities, even though they have value for the chemist and physicist, are of little help in educating nuclear engineers for future design and development work, and for training technicians to work in atomic power plants.

The Engineering Faculty Committee on Nuclear Education at the University of Washington has given this matter a great deal of thought. Our committee has come to the conclusion that a complete nuclear plant in the 5000-kilowatt range, located on or near the campus, would be the best educational aid for engineering students and technicians. Such a plant would also supply the University with a new and needed source of firm power and heat. Moreover, it would permit experimentation, development, and cost studies under practical operating conditions. It would serve practically every field of engineering involved in the application of atomic power. It would give useful information to guide the subsequent development of large-scale power plants and would be invaluable in the training of the personnel required to operate and maintain such plants.

The Atomic Energy Commission is planning to spend millions of dollars on the power reactor experiments described so briefly in this article. Serious consideration should also be given by the Commission and by the Congress of the United States to a partnership plan with several of the large engineering schools of this country to install different types of nuclear power plants in the 5000-kilowatt range on or near the campuses of these schools. The capital outlay involved would not exceed $10,000,000. The investment would stimulate tremendously the development of the atomic power industry in America and help to maintain our position of leadership in this new field. If the reports from the Geneva Conference of 1955 are accurate, that position is even now being seriously challenged by scientists and engineers in foreign countries.

ACKNOWLEDGMENTS

The author acknowledges his indebtedness for source material for this article to the Semi-Annual Reports of the United States Atomic Energy Commission and to publications of Henry D. Smyth, formerly AEC Commissioner.

Miscellaneous Publications: 1954-55

Humanistic-Social Studies

CHAPMAN, S. W., "The Right of Revolution and the Rights of Man," *Yale Review,* Summer, 1954.

SKEELS, D., "The Function of Humor in Three Nez Perce Myths," *American Imago.* Vol. XI (Fall, 1954).

———, "A Classification of Humor in Nez Perce Mythology," *Jour. Am. Folklore,* Vol. 67 (Jan–Mar., 1954).

SOUTHER, J. W., "Helpful Hints on Speaking," *Wash. Engineer,* Feb., 1953.

———, *A Guide to Technical Writing,* Uni. Wash. Press, Aug., 1953.

———, *ibid.,* 2nd ed., Aug., 1954.

Environmental Research Laboratory

KUSIAN, ROSS N., "Instrumentation for Industrial Hygiene and Air-Pollution Developed at the Environmental Research Laboratory, Part II: Stack-Sampling Equipment; Part III: Controlled Atmosphere Chamber," *The Trend in Engineering,* Vol. 7, No. 1 (Jan., 1955).

General Engineering

WILCOX, E. R., "Enrollment Trends, 1946–56, College of Engineering, University of Washington," *Puget Sound Eng.,* Vol. IX, No. 2 (Feb., 1955).

Civil Engineering

(Continued from page 23)

Publications

(Continued)

(with D. Vasarhelyi), Ship Structure Committee Serial No. SSC-75, March, 1955.

HENNES, R. G., "Highway Research," *Proceed.,* N.W. Conf. on Road Build., 1954.

———, "Highway Taxation," *Proceed.,* North Amer. Gas. Tax Admin. Conf., 1954.

———, "Incremental Cost Theory," *Proceed.,* Highway Research Board, 1955.

———, "Highway Classification," *Proceed.,* Calif. Street and Highway Conf., 1955.

———, "State Highway Research Councils," *Proceed.,* N.W. Conf. on Road Build., 1955.

OPSAL, F. W., "Analysis of Two- and Three-Dimensional Ground-Water Flow by Electrical Analogy," *The Trend in Engineering,* Vol. 7, No. 3 (July, 1955).

RASUL, A-R. S., "Strength of Trussed Columns" **(with S. Sergev),** *The Trend in Engineering,* Vol. 7, No. 3 (July, 1955).

SAVIKKO, E. R., "Slip of Joints Under Static Loads" **(with R. A. Hechtman, D. R. Young, and A. G. Chin),** ASCE *Proceed.,* Separate No. 484, Sept., 1954.

SERGEV, S., "Strength of Trussed Columns" **(with A-R. S. Rasul),** *The Trend in Engineering,* Vol. 7, No. 3 (July, 1955).

SYLVESTER, R. O., "A Study of the Sewage Disposal Problem in the Seattle-Everett Interurban Area" **(with K. R. Jones)** Report to Washington State Pollution Control Commission, May, 1955.

———, "A Critical Appraisal of Sewage Works Operation and Design," *Sew. and Ind. Wastes,* Vol. 27, No. 7 (July, 1955). EES Reprint No. 99.

VASARHELYI, D. D., "A Resistance-Wire Grid System," *The Trend in Engineering,* Vol. 7, No. 2 (Apr., 1955).

———, "Final Report on Welded Reinforcement of Openings in Structural Steel Tension Members" **(with R. A. Hechtman),** Ship Structure Committee Serial No. SSC-75, March, 1955.

YOUNG, D. R., "Slip Joints Under Static Loads" **(with R. A. Hechtman, A. G. Chin, and E. R. Savikko),** ASCE *Proceed.,* Separate No. 484, Sept., 1954.

Graduate Theses: 1954-1955

M.S. in Civil Engineering

EES: Engineering Experiment Station Fellow

BOUGHNER, RICHARD C.: An Investigation of Subsurface Water Currents in Lake Washington Around Mercer Island, Including Design of Suitable Floats.

CHHABRA, SAT PAL: Thermal Stresses in Cellular and Plate Structures.

CORTHELL, ALAN N.: Effects of Temperature Variations upon Subgrade Moisture Contents. (EES)

DULAGIL, HASAN N.: The Evaluation of Lateral Building Motion Due to Earthquakes.

FLINT, THOMAS R.: Behavior of Large Bolted Joints in the Design Range. (EES)

HOBBS, SAM H.: An Investigation of the Relationships of Specific Conductance Turbidity, Oxidation Reduction Potential, and Chlorine Residual on the Disinfection of Sewage with Chlorine.

HSIEH, YUAN YU: Structural Behavior of Beam and Column Joints in Reinforced Concrete Building Frames. (EES)

JOHNSON, WILLIAM E.: Drainage of Sands.

KNUDSON, RODNEY O.: Behavior of Box Beams Under Pure Bending. (EES)

KOEPSELL, PAUL L.: Stress-Slip Relationships in Bolted Joints.

LEE, HARRY R.: Comparative Shear Tests for the Analysis of the Stability of Selected Aggregates. (EES)

OPSAL, FINN W.: Analysis of Two Dimensional and Three Dimensional Ground Water Flow by Electrical Analogy. (EES)

POGGE, ERNEST C.: Short Term Streamflow Forecasting from Precipitation Data.

QUINN, PETER E.: A Machine to Produce Desired Saturated Samples in the Study of Electro-Osmosis of Clay.

THERRIAULT, GEORGE W.: Brittle Fracture in Structural Steel Plates. (EES)

TSAO, WILLIAM S.: A Study of Sewage Movement in Puget Sound: A Model Study.

YAMANE, GEORGE: Subgrade Frost Action and Related Soil Properties.

SOME HIGHLIGHTS ON GRADUATE STUDY IN ENGINEERING

(Continued from page 1)

regarded as leaders in their own fields, nor can it be by those who would live a complete life.

Faculty

Graduate faculties should not be too homogeneous. The students should be blown on here by many winds of doctrine so that they will not later be too easily blown about by them. Rationalist and empiricist, mathematician and historian, formalists, and those who care little for convention, all have a place provided they do not insist too violently that there is no place for the others.

A graduate faculty must grow, and this is true of the individuals and of the organism. Growth comes from exchange of views—of many views, of discordant views.

A graduate teacher must be honest and must be active in research which means that he must with honesty and humility seek truth and pursue it, he must be intelligent and well-informed, he should be broadly educated and have had experience that is varied . . . he must somehow inspire students to emulation and to subsequent independent production.

Administration*

Last and perhaps most difficult of all, the administration must itself have the spirit of dedication to the advancement of knowledge without which no graduate school can become really great. Such a spirit is reflected in an ability to recognize:

1. That in evaluating teaching loads account must be taken of the greater time required for preparation of graduate subjects. Graduate courses should be under constant change with new knowledge being fed in as soon as it becomes available.
2. That research, development, and creative design, which demand a major portion of the professor's time, are part and parcel of the graduate teaching job.
3. That the supervision of thesis research is time consuming even though it is also a rewarding educational duty.
4. That the best graduate programs are based upon the strength of particular faculty members rather than upon any fixed curriculum content.
5. That a strong graduate engineering program requires equally strong independent programs in the basic sciences.

To meet the above responsibilities involves an annual cost per student from two to ten times as great as that required to educate an undergraduate.

No school of engineering should consider instituting a graduate program unless it is willing and able to provide the additional funds required.

* From "Report of the Committee on Evaluation of Engineering Education," ASEE, 1952-1955.

HOW TO BE EFFICIENT, WITH FEWER VIOLINS

The following is the report of a Work Study Engineer—a specialist in Method Engineering—after a visit to a symphony concert at the Royal Festival Hall in London.

FOR CONSIDERABLE PERIODS the four oboe players had nothing to do. The number should be reduced and the work spread more evenly over the whole of the concert, thus eliminating peaks of activity.

All the twelve violins were playing identical notes; this seems unnecessary duplication. The staff of this section should be drastically cut. If a larger volume of sound is required, it could be obtained by electronic apparatus.

Much effort was absorbed in the playing of demi-semi-quavers; this seems to be an unnecessary refinement. It is recommended that all notes should be rounded up to the nearest semi-quaver. If this were done it would be possible to use trainees and lower-grade operatives more extensively.

There seems to be too much repetition of some musical passages. Scores should be drastically pruned. No useful purpose is served by repeating on the horns a passage which has already been handled by the strings. It is estimated that if all redundant passages were eliminated the whole concert time of two hours could be reduced to twenty minutes and there would be no need for an intermission.

The conductor agrees generally with these recommendations, but expressed the opinion that there might be some falling off in box-office receipts. In that unlikely event it should be possible to close sections of the auditorium entirely, with a consequential saving of overhead expenses, lighting, attendance, etc. If the worst came to the worst, the whole thing could be abandoned and the public could go to the Albert Hall instead.

Anonymous memorandum circulating in London, 1955, *via* HARPER'S MAGAZINE, June, 1955.

PUBLICATIONS

of the

ENGINEERING EXPERIMENT STATION

UNIVERSITY OF WASHINGTON

Requests for copies of publications should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

BULLETINS

48. The Influence of Pipe Thickness on Re-Entrant Intake Losses. Charles William Harris, 35 pp. 1928.
54. Elimination of Hydraulic Eddy Current Loss at Intake. Charles W. Harris. 30 pp. 1930.
55. Vacuum-Tube Control for Electric Wind-Tunnel Balances. Fred S. Eastman. 20 pp. 1931.
56. Constant Flow Characteristic of the Plane Orifice in Proximity to Side Walls. Charles William Haris. 18 pp. 1931.
58. Preliminary Tests of Thirteen Washington Coals in a Powdered Coal Boiler Plant at the University of Washington. George Samuel Wilson, Harry Fagan Yancey, and Joseph Daniels. 27 pp. 1931.
60. An Electromagnetic Balance for Force Measurement of Current Control. Fred Scoville Eastman. 29 pp. 1932.
61. Hydraulic Flow Characteristics of a Square-Edged Intake. Charles William Harris. 21 pp. 1932.
67. The Doherty Washer Cooler. Sybren Ruurd Tymstra. 61 pp. 1932.
69. Studies in Hydrogenation of Certain American Coals. Warren L. Beuschlein, Bert E. Christensen, and Calvert C. Wright. 24 pp. 1933.
72. The Derivation of the Mean Temperature Difference Between a Saturated Gas and a Cooling Liquid, and also the Derivation of the Mean Velocity of Such Gas. Sybren Ruurd Tymstra. 19 pp. 1933.
74. The Deformation of Hard Grade Reinforcing Steel During and After Construction in a Reinforced Concrete Building. Sergius Ivan Sergev. 33 pp. 1933.
75. The Water Tube Gas Condenser. Sybren Ruurd Tymstra. 24 pp. 1934.
77. A Study of Fundamental Relations of the Mathematical Theory of Elasticity. Arthur Melvin Winslow. 25 pp. 1934.
81. Influence of Two Secondary Factors in Weir Measurement. Charles William Harris. 16 pp. 1935.
84. Equations for Calculating Three Phase Symmetrical Components. Gordon Russell Shuck. 32 pp. 1935.
85. Discharge of Three Commercial Cippoletti Weirs. Robert Bowman Van Horn. 32 pp. 1935.
87. Open Water Testing of Ship Models. Thomas McKie Rowlands. 20 pp. 1935.
88. The Properties of Quartz Sands Washed from Kaolins of the Pacific Northwest. Hewitt Wilson and Frank Joseph Zvanut. 42 pp. 1936.
90. Hydroelectric Power in Washington. Part IV, Regional Electric-Power Transmission. The Grid System. Carl Edward Magnusson. 51 pp. 1936.
91. The Analysis and Control of Landslides. Robert Graham Hennes. 57 pp. 1936.
92. Moment Equations. A Method of Analysis for Continuous Beams and Rigid Frames. Alfred Jensen. 88 pp. 1937.
93. Electric Power Markets in Washington. Part I, Electric Heating of Residences. Carl Edward Magnusson. 40 pp. 1937.
94. Evaporation and Surface Cooling. George Samuel Wilson and William Lyle Dudley. 18 pp. 1937.
96. Hydroelectric Power in Washington. Part VI, International Boundary Waters. Carl Edward Magnusson. 17 pp. 1937.
98. Geology and Its Relation to the Occurrence of Oil in Washington. Charles Edwin Weaver. 16 pp. 1938.
100. Modernization of a Transit System. Factors that Determine the Choice of a Vehicle. George Lisle Hoard. 36 pp. 1940.
101. Buckling Criteria and Design of Two-Story Columns. Sergius I. Sergev. 48 pp. 1940.
102. An Investigation of Prestressed Stays. T. M. Rowlands and F. C. Smith. 36 pp. 1941.
103. Bismuth Bridge Magnetic Flux Meter. George Sherman Smith. 48 pp. 1940.
104. The Telechronometer, Telephone Service Measurement in Units of Time. Lyall Baker Cochran. 68 pp. 1941.
106. The Shearing Strength of Cement Mortar. Frederick C. Smith and Robert Q. Brown. 32 pp. 1941.
107. A Geologic Interpretation of the Failure of the Cedar Reservoir, Washington. J. Hoover Mackin. 30 pp. 1941.
108. Silica Sapds of Washington. Hewitt Wilson, Kenneth G. Skinner and Albert H. Couch. 76 pp. 1942.
109. The Number of Teeth in Contact as a Vibration Factor in Involute Cut Gears. Sybren Ruurd Tymstra. 16 pp. 1942.
110. Solutions for Torsional Vibration Frequencies by Energy Method. Arthur Melvin Winslow. 22 pp. 1943.
111. Stabilized Earth Blocks for Protective Construction. Robert G. Hennes. 24 pp. 1943.
112. Hydraulic Models. Charles W. Harris. 17 pp. 1944.
114. The Effect of Shearing Forces on the Deflection and Strength of Beams. Sergius I. Sergev. 20 pp. 1947.
115. The Influence of Random Roughness on Flow in Pipes. Charles W. Harris. 19 pp. 1949.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part I, Investigations Prior to October, 1941. F. B. Farquharson. 103 pp. 1949.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part II, Mathematical Analyses. F. C. Smith and G. S. Vincent. 63 pp. 1950.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part III, The Investigation of Models of the Original Tacoma Narrows Bridge Under the Action of Wind. F. B. Farquharson. 125 pp. 1952.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part IV, The Investigation of Models of the New Tacoma Narrows Bridge Under the Action of Wind. F. B. Farquharson. 104 pp. 1954.
116. Aerodynamic Stability of Suspension Bridges with Special Reference to the Tacoma Narrows Bridge. Part V, Extended Studies: Logarithmic Decrement, Field Damping, Prototype Predictions, Four Other Bridges. G. S. Vincent. 104 pp. 1954.
117. Production of Wood Coke from Waste Wood. Warren L. Beuschlein. 40 pp. 1950.
118. Investigations in Aeronautics from the Department of Aeronautical Engineering. Edited by R. M. Rosenberg. 120 pp. 1951.
119. The Extremum Principles of the Mathematical Theory of Elasticity and Their Use in Stress Analysis. (The Walker-Ames lectures of the Spring Quarter, 1950.) W. Prager (Brown University). 30 pp. 1951.

REPORTS

2. Iron and Steel Manufacture in Washington, Oregon. California, and Utah. Joseph Daniels. 69 pp. 1929.
3. Coal in Washington. Joseph Daniels. 17 pp. 1934.
4. Water Resources of Washington. Richard Gaines Tyler. 61 pp. 1938.
6. Chemical Utilization of the Subbituminous Coals of Washington. Lorentz A. Conradi. 83 pp. 1950.

TECHNICAL NOTES

3. The Theory of Fractional Parts Developed for Structural Beam-Column Members Preceded by an Elementary Discussion of Simple Beam and Column Design. Sybren Ruurd Tymstra. 32 pp. 1943.
4. Gaging Chart for Horizontal Cylindrical Tanks with Flat Heads or with Convex Heads. Sybren Ruurd Tymstra. 4 pp. 1944.
5. Gaging Chart for Cylindrical Tanks with Different Types of Heads. Sybren Ruurd Tymstra. 7 pp. 1945.
6. The Heat Pump for Residential Heating. G. S. Smith, H. Christensen, and A. Presson. 23 pp. 1948.